THE SEPTEMBER SCIENTIFIC MONTHLY

Edited by

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Published by THE SCIENCE PRESS
LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.
FOR THE
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
SMITHSONIAN INSTITUTION BUILDING, WASHINGTON, D. C.

NEW BOOKS OF SCIENTIFIC INTEREST

Mathematics and the Imagination. E. KASNER and J. NEWMAN. Illustrated. 369 pp. 1940. Kingsport.

Two mathematicians present to the reader the infinitesimally small and unconceivably large through the medium of higher mathematics. They also delve into the laws of chance and probability and the mathematics of change and growth.

Fundamentals of Physical Science. K. B. KRAUSKOPF. Illustrated. x + 660 pp. $3.50. 1941. McGraw-Hill.

Placing emphasis on the methods of scientific reasoning rather than the results, this textbook is designed for students or laymen who wish a general knowledge of the physical sciences. Physics, chemistry, astronomy and geology are presented as a unified field.

The Orientation of Animals. G. FRAENKEL and D. L. GUNN. Illustrated. vi + 352 pp. $6.00. 1940. Oxford.

This treatise covers the kineses, taxes and compass reactions of animals. The first part describes the main categories of these reactions for undergraduates and students; the second part reviews recent work for advanced students and research workers.

The Telephone in a Changing World. M. M. DILTS. Illustrated. xiv + 219 pp. $2.50. April, 1941. Longmans, Green.

Extensive research has been made in an attempt to give both technical and general information concerning the telephone. The book recounts its social and economic effect, and describes many aspects of telephonic progress, including the development of by-products.

Butterflies. R. W. MACEY and H. H. SHEPARD. Illustrated. vii + 247 pp. $3.50. July, 1941. Minnesota.

The first part tells about butterflies in general, their natural history, methods of collection, etc. A chapter is then devoted to each of the nine families in Northern United States in which detailed descriptions of different species are given.

Textbook of Psychiatry. A. NOYES and E. HAYDON. 3rd ed. x + 315 pp. $2.50. 1940. Macmillan.

The book opens with a discussion of the nature of mental processes in general. This is followed by an examination of the causes, symptoms and cures of eighteen diseases. A discussion of the practical aspects of nursing closes the book.

New England's Fishing Industry. A. ACKERMAN. Illustrated. xix + 294 pp. $4.00. July, 1941. Chicago.

The author undertakes to describe the commercial fisheries of New England in all of its phases. Emphasis throughout the volume, however, is placed upon distributional phenomena and the broader aspects of regional geography

Commercial Flower Forcing. A. LAURIE and G. H. PIESCH. Illustrated. vi + 565 pp. $4.50. 1941. Blakiston.

The fundamentals of modern floriculture and their practical application to the culture of greenhouse crops are presented by two professors at Ohio State University. Discussions of gravel culture and growth promoting substances are included in the volume.

Conditioned Reflexes and Psychiatry. The late I. P. PAVLOV. Translated and Edited by W. H. GANTT. Illustrated. 199 pp. May, 1941. International Publishers.

This is the second volume of Pavlov's addresses and unpublished papers. The two volumes form a complete collection of Pavlov's public lectures on conditioned reflexes and psychiatry from 1903, when he was awarded the Nobel Prize, to his death in 1936.

A Family Doctor. I. J. WOLF. Illustrated. 315 pp. $2.00. 1940. Fortuny.

This book contains observations by a physician after fifty years' practice concerning his own life, relationships between the physician and the patient, the cost of doctoring, vivisection, popular fads and on the future prospects of medicine.

Man Stands Alone. J. HUXLEY. x + 297 pp. $2.75. March, 1941. Harper.

Mr. Huxley, the well-known English biologist and writer, has collected into one volume a series of fourteen essays, written since 1927, on various subjects ranging from "The Courtship of Animals" and "The Intelligence of Birds" to "Scientific Humanism" and "Religion as an Objective Problem."

Island Holiday. ALICE WRIGHT. Illustrated. xiii + 296 pp. $2.00. 1941. Stokes.

This is the story of an expedition to Bermuda, based upon the author's own adventures collecting specimens and executing undersea photography and painting, as well as upon the experiences and reports of other students of marine life.

Into China. E. BIGLAND. Illustrated. 298 pp. $3.00. 1940. Macmillan.

The narrative of an American woman who travelled over the famous Burma Road connecting India with Chungking, the present capital of China. She travelled with an ammunition convoy and encountered a wide variety of perils and adventures.

The Flower Family Album. H. F. FISCHER and G. HARSHBARGER. Illustrated. 125 pp. $2.50. June, 1941. Minnesota.

This is a book containing sketches of flowers, vegetables and weeds arranged in family groups. Bits of garden folklore are added to the scientific descriptions of the plants and their relationships. Hints for the gardener, amateur botanist and teacher are also included.

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SEPTEMBER, 1941

CHEMICAL PROPERTIES OF VIRUSES

By Dr. W. M. STANLEY

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SIX years ago over a hundred viruses were recognized, yet it would have been virtually impossible to write then on the present subject, for at that time practically nothing was known about the chemical properties of viruses. These agents, which are responsible for untold millions of illnesses and deaths amongst people, animals and plants, were recognized only by means of the diseases which they caused, diseases such as smallpox, parrot fever, yellow fever, St. Louis encephalitis, poliomyelitis, horse encephalomyelitis, foot-and-mouth disease of cattle, louping ill of sheep, hog cholera, rabies, dog distemper, fowl pox, certain types of tumorous growths in fowls and other animals, jaundice of silkworms and various yellows and mosaic diseases of plants. The general nature of the agents responsible for such diseases was a matter of much conjecture. When placed in certain living cells, these agents could multiply, mutate or undergo variation to form new strains, and induce immunity. They seemed to have many of the properties of very small living organisms such as the bacteria; yet, unlike most bacteria, they were too small to be seen by means of the ordinary microscope and could not be induced to multiply in the absence of living cells. They were mysterious, invisible somethings which, in the absence of living cells, appeared as harmless and as lifeless as pebbles on the beach, but which, even after years of inactivity, were ready to spring into action and cause disease and death when introduced by chance or by design into certain living cells. By virtue of their ability to mutate or form variants, they were able to change and adapt themselves to new surroundings and conditions and thus not only to retain but to enlarge their place in a changing world. The fact that the viruses were recognized only by means of the diseases which they caused and the fact that these diseases were becoming of increasing importance only served to add to the mantle of mystery which surrounded them and to intensify the challenge which they presented.

In 1935 a tangible characteristic material possessing virus activity was isolated from Turkish tobacco plants diseased with tobacco mosaic virus and made available for chemical study. The material, which appeared to be a nucleoprotein of enormous size possessing quite distinctive properties, was obtained from every lot of diseased Turkish tobacco plants examined. The same material was obtained from various, in some instances unrelated, species of mosaic-diseased plants. Slightly different, although closely related, nucleoproteins were isolated from plants diseased with strains of tobacco mosaic virus. The purified preparations possessed proper-

FIG. 1. TOBACCO MOSAIC VIRUS
EACH NEEDLE-LIKE CRYSTAL CONTAINS MANY MOLECULES OF VIRUS AND HAS BEEN REFERRED TO AS PARA-CRYSTALLINE, SINCE X-RAY DATA INDICATE A LACK OF INTERMOLECULAR REGULARITY IN THE DIRECTION OF THE LENGTH. MAGNIFICATION ×753.

ties which were characteristic, not of the hosts in which they were produced, but of the virus or virus strain. An unexpected finding was that mosaic-diseased Turkish tobacco plants may contain as much as one part per 500 of the high molecular weight nucleoprotein. The amount of material isolable varied in other cases and appeared to depend upon the host and the strain of the virus, and in some instances was only a small fraction of the amount obtainable from mosaic-diseased Turkish tobacco plants. To date all attempts to separate tobacco mosaic virus activity from the nucleoprotein have failed and the material, which can be obtained in the form of long thin paracrystalline needles (Fig. 1), has come to be regarded as crystalline tobacco mosaic virus. The material provided the first information regarding the general nature and chemical makeup of this virus and, although its exact nature was and remains a debatable matter, its isolation removed some of the mystery surrounding the general nature of viruses and served as an incentive for the search for similar materials in the case of other virus diseases.

The isolation of crystalline tobacco mosaic virus was followed by the preparation from various virus-diseased tissues of over 20 crystalline or amorphous materials possessing some of the properties of the respective viruses or virus strains. In not every case has it been proved that the material is essentially pure and consists of virus. However, in several cases it has been proved beyond a reasonable doubt that the materials consist of the respective viruses in an essentially pure state, and in no instance has virus activity been obtained in the absence of the characteristic material. Due chiefly to our older ideas of the nature of viruses, the crystallinity of some of the purified preparations may appear at first as a rather spectacular property; yet, if these materials are considered as proteins, crystallinity becomes an expected rather than an unexpected property, for many proteins are known to be crystallizable. Careful and mature consideration will reveal that crystallinity or the lack of crystallinity is of no special importance in connection with the purity or general nature of a material, but is important chiefly because it makes it possible to obtain certain solubility and x-ray data which would otherwise be unobtainable.

There is not sufficient space for a detailed discussion of the chemical properties of all the preparations of purified viruses and, in order to provide you with an idea of their general chemical properties, I shall devote most of the text to the two viruses which have been extensively investigated from this standpoint, namely, tobacco mosaic and tomato

bushy stunt viruses. These are typical viruses with respect to the essential and recognized characteristics of a virus; yet it must be admitted that each has certain special properties which make it an unusually favorable material for experimental work. Thus, tobacco mosaic virus is among the most stable of all viruses and reaches a concentration in Turkish tobacco plants which is far greater than that reached by most viruses in their respective hosts even under the most favorable conditions, and bushy stunt is the only virus which has been obtained in the form of large rhombic dodecahedric crystals (Fig. 2). However, there is no more reason for regarding these viruses as atypical because of such special properties than for regarding vaccine virus as atypical because of its unusually large size or foot-and-mouth disease virus as atypical because it is the smallest of all viruses. Tobacco mosaic and bushy stunt are plant diseases, and it has been argued that the viruses of plants differ fundamentally from those of animals and, hence, that information gleaned from studies on plant viruses has but little significance in connection with animal viruses. This argument was based chiefly on the failure of plant viruses to grow in animals and of animal viruses to grow in plants. However, because there is no difference in the fundamental virus properties, I have always considered this to be an erroneous viewpoint. Within the past few years, Fukushi secured strong evidence that rice dwarf disease virus multiplies in its insect vector, and Kunkel and more recently Black have obtained experimental evidence which demonstrates beyond a reasonable doubt that aster yellows virus can multiply in its insect vector. The growth of a plant virus in an animal provides further evidence in support of the conclusion that there is no fundamental difference between the viruses of plants and those of animals. Different viruses must of necessity differ in certain of their properties, and a composite picture of viruses as a group will not be obtained until many viruses have been studied.

Tobacco mosaic virus appears to be a conjugated protein containing about 95 per cent. protein and 5 per cent. nucleic acid. The latter has been found to contain uridylic acid, guanine, cytosine and adenine, and to give a test for a pentose but not for a desoxypentose and, hence, appears to be of the yeast rather than of the thymus nucleic acid type. Bushy stunt virus appears to contain about 83 per cent. protein and 17 per cent. of a nucleic acid of the same kind as that found in tobacco mosaic virus. Tobacco ring spot virus contains 40 per cent. nucleic acid, the highest percentage yet found in a virus. This is also of the yeast nucleic acid type, but the elementary bodies of vaccinia and of psittacosis have been found to give a test characteristic of thymus nucleic acid. With the exception of a bacteriophage preparation obtained by Kalmanson and Bronfenbrenner and considered to be a simple protein, all the purified virus preparations so far obtained have been at least as

FIG. 2. TOMATO VIRUS
CRYSTALS OF TOMATO BUSHY STUNT VIRUS. MAGNIFICATION × 209.

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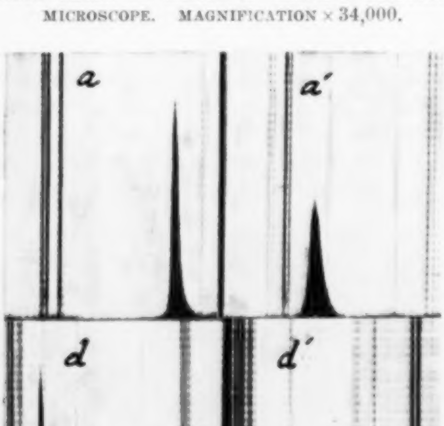
FIG. 3. TOBACCO VIRUS MOLECULES
MICROGRAPH OF MOLECULES OF TOBACCO MOSAIC VIRUS TAKEN BY MEANS OF THE RCA ELECTRON MICROSCOPE. MAGNIFICATION × 34,000.



G. A. Miller

FIG. 4. ELECTROPHORETIC PATTERN
SHOWN BY A 0.1 PER CENT. SOLUTION OF TOBACCO MOSAIC VIRUS. A AND D REPRESENT THE ASCENDING AND DESCENDING BOUNDARIES AT THE START OF THE EXPERIMENT. A′ AND D′ REPRESENT THE SAME BOUNDARIES AT THE END.

complex as a nucleoprotein. This fact may eventually prove of prime importance, for it may be recalled that chromosomes appear to consist almost exclusively of nucleoprotein. Some viruses appear to contain in addition some carbohydrate, others lipoid, and still others appear to be so complex that they may be indistinguishable from bacteria in composition. The distribution of amino acids in the protein component of tobacco mosaic virus has been studied, and at present only the apparent absence of histidine and the lack of a preponderance of arginine and of other known basic amino acids are noteworthy. The complete amino acid distribution in strains of this virus and in other viruses has not been determined as yet, although such studies are in progress and may provide a clue to the reason for the specificity of viruses and possibly a means for distinguishing not only between viruses but also between the strains of a virus. For example, with Dr. Knight it has already been found that the amounts of certain aromatic amino acids vary with the strain of the virus. Analysis of 12 preparations of tobacco mosaic virus indicated the presence of 3.8, 4.5 and 6.0 per cent. of tyrosine, tryptophane and phenylalanine, respectively, with maximum deviations of ± 0.1 per cent. for the tyrosine and ± 0.2 per cent. for the tryptophane and phenylalanine values. The corresponding values in the case of the Holmes ribgrass strain of tobacco mosaic virus were 6.4, 3.5 and 4.3 per cent. and 3.8, 1.4 and 10.2 per cent. in the case of the closely related cucumber mosaic virus 4. These results are of considerable importance, since they show that the mutation of tobacco mosaic virus with the formation of a new strain which in turn causes a new disease may be accompanied by changes in the amino acid composition of the virus. The fact that the phosphorus content of the different strains was approximately the

FIG. 5. ABSORPTION PICTURES OF TOBACCO MOSAIC VIRUS SHOWING TWO SHARP SEDIMENTING BOUNDARIES.

same may be taken as an indication of the absence of significant quantitative differences in the nucleic acid component of the strains. Because of the close similarity between the properties of viruses and those of the bearers of heredity, it is obvious that an extension of this work should provide information of a fundamental nature regarding the structural changes involved in the mutation within chromosomes. The nature of the structural alterations which must be responsible for changes in the virulence of a virus may also be elucidated.

Tobacco mosaic virus contains 50 per cent. carbon, 7 per cent. hydrogen, 16 per cent. nitrogen, 0.6 per cent. phosphorus and 0.2 per cent. cysteine sulfur. It has an isoelectric point at pH 3.5, a density of 1.37, and at a concentration of about 2 mg per cc a sedimentation constant of 174×10^{-13} cm in unit centrifugal field and a diffusion constant of 3×10^{-8} sq. cm. per sec. It has been estimated by indirect methods that the particles of the virus are remarkably anisometrical and are about 400 mμ in length and about 12 mμ in diameter. Recently, by direct observation by means of the electron microscope, Dr. Anderson and I found that most of the particles in a dilute solution of the virus are about

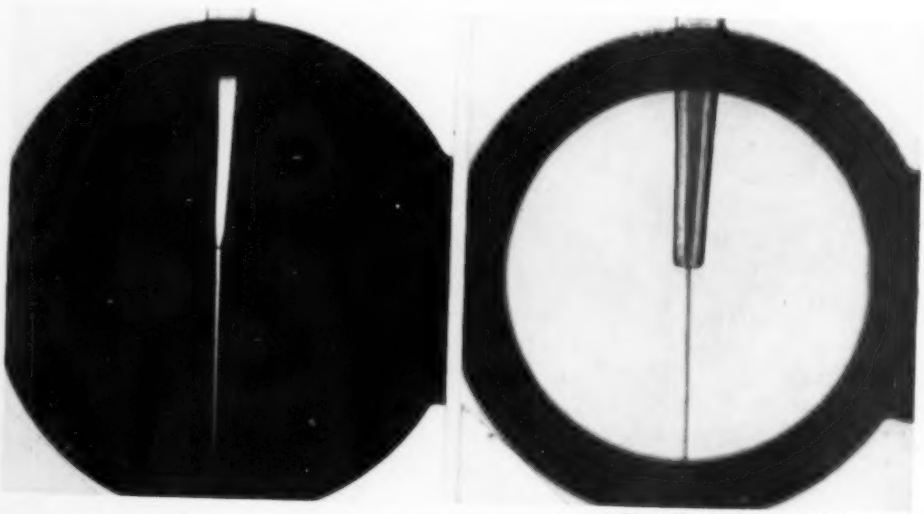


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FIG. 6. DOUBLY REFRACTING STREAM OF TOBACCO MOSAIC VIRUS FLOWING FROM A PIPETTE. *Left:* PHOTOGRAPHED BETWEEN CROSSED POLAROID PLATES ARRANGED SO THAT EACH VIBRATION DIRECTION OF THE POLAROID PLATES MAKES AN ANGLE OF 45° WITH DIRECTION OF FLOW. *Right:* SAME SYSTEM PHOTOGRAPHED BETWEEN PARALLEL POLAROID PLATES.

J. A. Carlile

FIG. 7. FISH IN VIRUS SOLUTION

FISH SWIMMING THROUGH A 0.7 PER CENT. SOLUTION OF TOBACCO MOSAIC VIRUS. PHOTOGRAPHED BETWEEN CROSSED POLAROID PLATES. LIGHT AREAS SHOW DOUBLE REFRACTION DUE TO ORIENTATION OF ROD-LIKE MOLECULES OF VIRUS CAUSED BY CURRENT SET UP BY MOVEMENT OF FISH.

J. A. Carlile

FIG. 8. OBJECT IN VIRUS SOLUTION

OBJECT MOVING FROM LEFT TO RIGHT THROUGH A 0.7 PER CENT. SOLUTION OF TOBACCO MOSAIC VIRUS. PHOTOGRAPHED BETWEEN CROSSED POLAROID PLATES. LIGHT, DOUBLY REFRACTING AREAS SHOW NATURE OF CURRENTS CAUSED BY MOVING OBJECT.

FIG. 9. SEDIMENTING BOUNDARY

ABSORPTION PICTURES SHOWING SEDIMENTING BOUNDARY OF TOMATO BUSHY STUNT VIRUS.

280 mμ in length and about 15 mμ in diameter (Fig. 3). Several kinds of evidence indicate that the molecular weight of tobacco mosaic virus is about 50 millions. The value of 17 millions, which was estimated several years ago when the asymmetry was unknown and which was based on an assumed asymmetry constant of 1.3, is incorrect. However, it is possible that different strains of tobacco mosaic virus may have different molecular weights, for the sedimentation constant of the aucuba mosaic strain is measurably larger than that of tobacco mosaic virus and the x-ray data indicate that the molecules of the former have the same diameter as that of the molecules of tobacco mosaic virus. Furthermore, Melchers and coworkers, in a study by means of the electron microscope, found the molecules of the two strains of tobacco mosaic virus with which they worked to have particle lengths of about 190 mμ and 140 mμ.

Tobacco mosaic virus gives a sharp boundary and migrates at a uniform rate in the Tiselius electrophoresis apparatus (Fig. 4). When carefully prepared, the virus gives a sharp boundary in the ultracentrifuge, but on treatment with salt at room temperature some of the particles appear to aggregate end-to-end to give a preparation which shows two boundaries in the ultracentrifuge. The second more rapidly sedimenting boundary is due apparently to a component formed by the end-to-end aggregation of pairs of molecules (Fig. 5). Further aggregation yields a very inhomogeneous product which shows a very broad boundary in the ultracentrifuge. The sedimentation constant of tobacco mosaic virus has been found to vary with the concentration, due apparently to interparticle forces which become of considerable magnitude in concentrated solutions. Solutions of tobacco mosaic virus

exhibit strong double refraction of flow and electrical double refraction, the former being due to the rod-like shape of the particle and the latter to the particle being asymmetrically charged, either permanently or as a result of the electrical field (Fig. 6). The fact that tobacco mosaic virus shows strong double refraction of flow may prove of considerable importance in apparently unrelated fields, for if necessary the virus could be prepared in pound lots or in larger amounts and used to study the flow currents in apparatus such as pumps and hydraulic rams or the nature of the flow when boats or projectiles move through a liquid (Figs. 7 and 8). Moderately concentrated solutions of the virus, when allowed to stand, separate out into two distinct layers, the lower of which is spontaneously doubly refracting and the upper of which shows double refraction only when caused to flow. Pellets of the virus obtained by ultracentrifugation are doubly refracting. The strains of tobacco mosaic virus and cucumber mosaic 3 and 4 viruses have properties somewhat similar to those just described. Latent mosaic virus of potato has a rod-like shape and appears to be even more asymmetrical than tobacco mosaic virus. The layering phenomenon, the change in sedimentation constant with concentration, and certain of Bernal's x-ray studies, of Lauffer's observations on the electro-optical effect and of Frampton's studies on the thixotropic character of tobacco mosaic virus indicate that in concentrated or moderately concentrated solutions there are interparticle forces

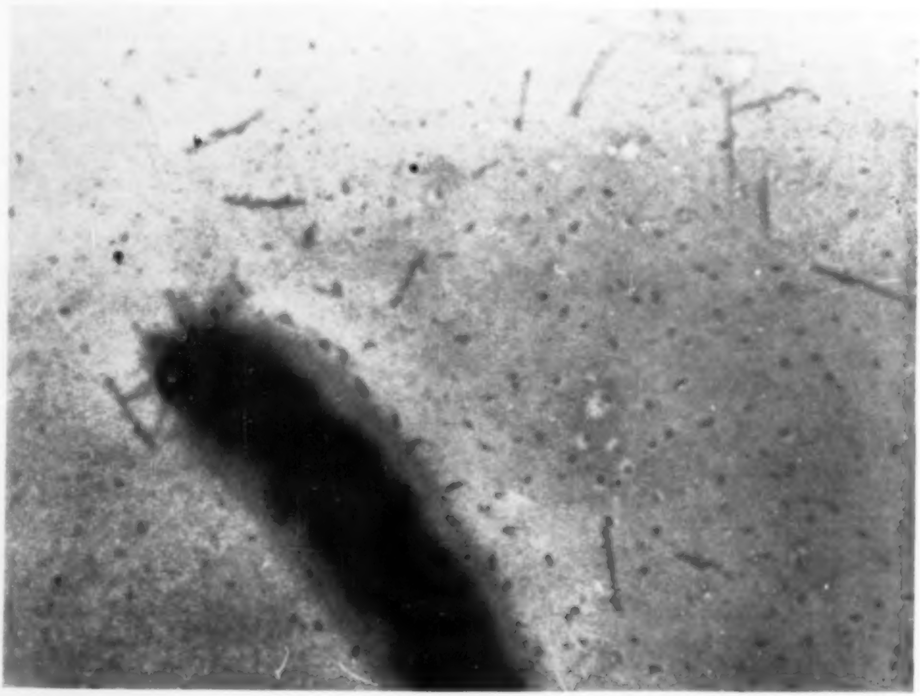

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FIG. 10. MIXTURE OF TOBACCO MOSAIC VIRUS WITH NORMAL RABBIT SERUM

THE CONTAMINATING BACTERIUM SERVES TO GIVE A GOOD IDEA OF THE RELATIVE SIZE OF THE MOLECULES OF VIRUS. ELECTRON MICROGRAPH WITH MAGNIFICATION × CA 37,000.

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FIG. 11. TOBACCO VIRUS WITH ANTI-TOBACCO VIRUS RABBIT SERUM
AN ELECTRON MICROGRAPH WITH MAGNIFICATION × CA 13,700.

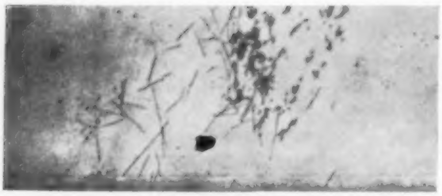
which are effective over large distances. Although in the past the existence of such long-range forces has been denied for theoretical reasons, Langmuir and Levine independently have recently shown that there are in fact good theoretical grounds for their existence. The demonstration of the existence of forces acting between molecules hundreds of Å units apart, and their acceptance from the standpoint of theory alone, may prove of great importance in connection with our theories of virus reproduction and other intracellular events such as the duplication of chromosomes.

The carbon, hydrogen and nitrogen contents of bushy stunt virus are about the same as those of tobacco mosaic virus. However, the phosphorus and sulfur contents of 1.5 and 0.4 to 0.8 per cent., respectively, are considerably larger than those of tobacco mosaic virus. Bushy stunt virus has a density of 1.35, a sedimentation constant of 132×10^{-13} and a diffusion constant of 1.15×10^{-7}. A molecular weight of about 8 million and a particle diameter of about 26 mμ may be calculated from these constants. Solutions of bushy stunt virus do not show double refraction of flow and the pellets obtained on ultracentrifugation are isotropic. The particles of the virus appear to be essentially spherical in shape. The purified preparations are homogeneous when examined in the ultracentrifuge or the Tiselius electrophoresis apparatus (Fig. 9). Bushy stunt virus does not appear to be susceptible to the peculiar aggregation which seems to be a characteristic of the rod-shaped viruses and, unlike the latter, the sedimentation constant is almost independent of the concentration. Several other viruses have been found to be essentially spherical in shape. Among these are alfalfa mosaic virus, which has a molecular weight of about 2 million and a diameter of about 16 mμ, and the Shope rabbit papilloma

virus, with a molecular weight of about 25 million and a diameter of about 40 mμ. The elementary bodies of vaccinia have a diameter of about 225 mμ. There is, therefore, a group of rod-shaped viruses and a group of viruses which are essentially spherical in shape, although with the development of more precise techniques some of the latter may be found to be definitely ellipsoidal in shape. It should be emphasized that each virus has a shape and a size which appear to be quite definite and characteristic, regardless of the conditions or the host in which the virus is produced. However, neither this statement nor the statements relative to the homogeneity of virus preparations in the ultracentrifuge or electrophoresis apparatus are meant to imply that all the particles in a given virus preparation are exact replicas. The fact that variants continually arise during the production of virus would always insure the presence in purified preparations of a small amount of closely related although slightly different particles. There is other evidence, such as that obtained by Loring in solubility studies on tobacco mosaic virus, which indicates that the purified virus preparations are not absolutely homogeneous chemically but consist of a family of very closely related structures. The general situation may not be far different from that which is now known to exist in the case of even very simple structures, such as sulfur, nitrogen and hydrogen, where families of isotopes are the rule rather than the exception. In this connection, it may be stated that the problems and relationships which obtain with the tremendous virus structures are not well clarified at present. However, from a practical standpoint, there has been little difficulty as yet, for there are several instances in which, according to present techniques, there is a very high degree of chemical homogeneity.

Tobacco mosaic, bushy stunt and other viruses which have been obtained in purified form are good antigens. It is necessary, however, to inject animals

FIG. 12. SEDIMENTATION DIAGRAM OF A MIXTURE OF TOMATO BUSHY STUNT VIRUS WITH ANTI-TOBACCO MOSAIC VIRUS RABBIT SERUM. AT THE CENTRIFUGAL FORCE USED, THE RIGHT-HAND PEAK, WHICH IS DUE TO THE SERUM PROTEIN BOUNDARY, IS PRACTICALLY STATIONARY, WHEREAS THE OTHER PEAK, WHICH IS DUE TO THE BUSHY STUNT VIRUS BOUNDARY, GRADUALLY MOVES TO THE LEFT. THE SEDIMENTATION CONSTANT OF THE BUSHY STUNT VIRUS IS ESSENTIALLY UNCHANGED, INDICATING LACK OF REACTION WITH THE ANTISERUM.



T. F. Anderson and W. M. Stanley

FIG. 13. MIXTURE OF VIRUSES

ELECTRON MICROGRAPH OF A MIXTURE OF TOBACCO MOSAIC AND BUSHY STUNT VIRUSES WITH ANTI-BUSHY STUNT VIRUS RABBIT SERUM. THE MOLECULES OF TOBACCO MOSAIC VIRUS ARE UNAFFECTED; THOSE OF THE BUSHY STUNT VIRUS ARE CLUMPED TOGETHER. MAGNIFICATION × CA 14,000.

with the viruses, for antibodies do not appear to be produced in plants. This may be due to the nature of plants for, despite much effort, no conclusive proof of the existence of antibodies in plants has been obtained, although Wallace secured some suggestive results with curly top virus. The serum of a rabbit injected with tobacco mosaic virus gives a specific precipitate with tobacco mosaic virus and specifically neutralizes tobacco mosaic virus activity. This reaction has been studied with Dr. Anderson by means of the electron microscope and the ultracentrifuge. Electron micrographs of a mixture of virus and normal rabbit serum show virus particles of normal size, indicating little or no adsorption of particles from normal serum on the virus molecules (Fig. 10). The sedimentation constant of tobacco mosaic virus is essentially unchanged in mixtures containing normal rabbit serum or antisera to bushy stunt, ring spot or latent mosaic viruses. However, electron micrographs of a mixture of tobacco mosaic virus and tobacco mosaic virus antiserum from rabbits show particles about 60 mμ wide, about 300 mμ long and having fuzzy profiles (Fig. 11). The increase in particle width and the fuzzy appearance are regarded as indicating that the ends of asymmetrically shaped molecules from the serum react specifically with the virus molecules. No reaction between anti-tobacco mosaic virus serum and bushy stunt virus was demonstrable either by means of the electron microscope or the ultracentrifuge (Fig. 12). Bushy stunt virus is, however, specifically precipitated by its own antiserum (Fig. 13). In general, a serological relationship may be demonstrated between different strains of the same virus, but not between different viruses. However, Bawden and Pirie have found that a serological relationship exists between tobacco mosaic and cucumber mosaic 3 and 4 viruses. This fact and the fact that other properties of these viruses are very similar may indicate a common origin for these viruses. Bawden and Pirie also noted that the precipitates of rod-shaped viruses with their antisera resembled those obtained with bacterial flagellar antigens, whereas those of the symmetrically shaped bushy stunt virus resembled those with somatic antigens. Tobacco mosaic virus has been found not anaphylactogenic by the Schultz-Dale technique and only weakly anaphylactogenic when tested *in vivo*.

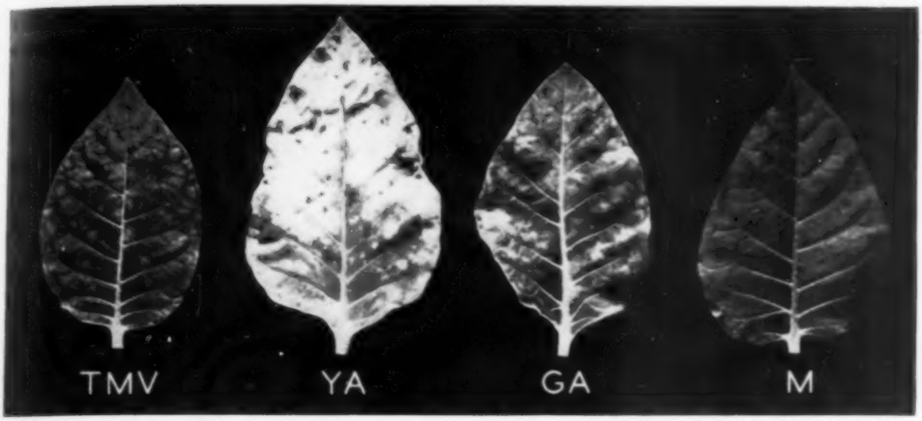
Viruses are inactivated when subjected to excessive amounts of acid, alkali, oxidizing agents, formaldehyde, urea, ultraviolet light or heat. In general, the rate and the amount of the inactivation vary with the virus and with the severity of the treatment. Tobacco mosaic virus is stable between about pH 2 and pH 8. At more acid or more alkaline reactions the nucleoprotein is denatured and broken up into material of low molecular weight, and the virus activity appears to be irreversibly lost. There is some evidence that the virus first breaks into fairly large pieces and these then continue to break up into progressively smaller pieces, but more data will be required before an exact picture of the process may be obtained. The disintegration of virus in urea provides another interesting process for study. In 6 M urea and 0.1 M phosphate buffer at pH 7,

tobacco mosaic virus is rapidly disrupted, with appearance of free sulfhydryl groups, into low molecular weight protein components which contain no nucleic acid, exhibit no double refraction of flow, are insoluble in dilute buffers, and possess no virus activity. The rate of the disintegration varies widely with the concentration of urea, the concentration of electrolyte, the type of electrolyte, the hydrogen-ion concentration and the temperature. The bonds which hold the component parts of the virus together appear to be released and satisfied by those of the urea, for the virus structure literally flies apart. It is obvious that studies on these split products should reveal information concerning the nature of the components making up the virus and perhaps furnish a clue as to the mode of synthesis of the virus. Materials similar in structure to urea, such as guanidine, as well as apparently unrelated substances, such as sodium dodecyl sulfate, also cause disintegration of the virus. Enzymes have been found to cause the breakup of certain viruses. Neither tobacco mosaic nor bushy stunt virus is split by trypsin, but this enzyme causes the rapid hydrolysis of alfalfa mosaic virus. Tobacco mosaic virus appears to be digested slowly by pepsin, although the rate of hydrolysis is much slower than might have been anticipated. All viruses appear to be denatured by heat, and the temperature at which denaturation occurs depends upon the virus and to some extent upon conditions such as the hydrogen-ion concentration and the kind of salts present.

In the heat and other types of denaturation reactions that have just been described, there is a more or less complete disintegration of the virus structure and the products which are formed do not have the properties which characterized the intact virus. They are of low molecular weight, do not react serologically with antiserum to virus, and do not induce the formation of antibodies which neutralize virus. It has been found possible, however, to inactivate viruses without such a complete disintegration of structure. When tobacco mosaic virus is treated with mild oxidizing agents, formaldehyde, nitrous acid or ultraviolet light, the properties of the resulting materials are, with the exception of virus activity, very similar to those of the intact virus. For example, the size and shape are not measurably affected, the materials give a precipitin reaction with antiserum to active virus, and, perhaps most important, the injection of the inactive materials gives rise to the production of antibodies which will specifically neutralize tobacco mosaic virus activity. It appears that these treatments cause no great change in the general topography of the virus structure, but bring about changes that are very small with respect to the structure as a whole but which are nevertheless sufficiently definite to cause the loss of virus activity. This fact may be quite important in connection with efforts to protect ourselves against the devastating effects of virus diseases. As you may know, in the three general methods of protection which are now employed, active virus plus immune serum, active virus usually of a strain that will cause a less severe disease, or inactivated virus is used to secure immunization. The second method is used extensively and successfully in the protection against smallpox, yellow fever and certain other virus diseases, and the third method, which has proved less satisfactory, has been used with claims for success for many viruses such as hog cholera, rinderpest, dog distemper, influenza, and others. It is now being widely employed in the case of equine encephalomyelitis virus. In the second method, the production of a strain which will cause an innocuous disease but which will immunize against virulent strains is most important. In the third method, the produc-

tion of an inactivated virus which will, upon injection, immunize against active virus is most important. It seems likely that many of the failures to achieve the latter result have been due to the use of methods of inactivation which cause too great a change in the structure of the virus. In our studies of the viruses which we have purified, we have found that the same procedure which will inactivate a given virus without causing widespread loss of structure and loss of characteristic antigenic properties will cause the complete disintegration and loss of characteristic antigenic properties of another virus. It is obvious, therefore, that it is of extreme importance that viruses be obtained in purified form and studied so that for each virus a method may be evolved for inactivating the virus without destroying its immunizing potency. The change in structure that results in inactivation need not necessarily be very great, and it may even be reversible. For example, we have found that the inactivation resulting from the addition of formaldehyde to tobacco mosaic virus may be reversed and active virus once again prepared from the inactive material. The fact that this reaction may be reversed is some indication that a major change in structure is not involved.

Closely related to the general problem of inactivating viruses with the least possible change in structure are the studies on ways and means of producing the less virulent strains of a virus which are so important in connection with the second general method of immunization. So far, the production of less virulent strains which have proved of great practical importance has been achieved by the simple expedient of passing the virus through another host. Thus, a strain of virus which will protect against smallpox may be obtained by infecting a calf with smallpox virus and reisolating the virus produced after several passages in calves. A useful strain of yellow fever virus was secured in a similar manner by Theiler by passage through mouse brains. The change in environment during the production of virus in the second host apparently results in the production or selection of a strain of virus which is much less virulent in the first host. Practically nothing is known as to why a less virulent strain is prepared or of the change in structure which must be involved. However, it does not appear unreasonable to expect that definite chemical reactions which result in a change in the structure of a given virus without causing inactivation will achieve the same result and yield strains of the virus, some of which may cause a less virulent disease and be useful for immunization against virulent strains. Leaves diseased with different strains of tobacco mosaic virus are shown in Figure 14. Some progress has been made in studies on methods for changing the chemical structure of tobacco mosaic virus without causing a loss of virus activity. Dr. Anson and I found that the sulfhydryl groups of the virus can be abolished by reaction with iodine and the altered virus still retains its normal biological activity as shown by the number of lesions it causes on *Nicotiana glutinosa* plants and by the characteristic disease produced in Turkish tobacco plants. Since the virus isolated from the latter plants had the normal number of sulfhydryl groups, the structural change caused by iodine treatment was not perpetuated in subsequent generations of the virus. Because of the possibility that the iodine-altered virus might be reduced to normal virus within the plant cells, other reactions of a less readily reversible nature were sought. With Dr. Miller it was demonstrated that most of the amino groups of tobacco mosaic virus may be acetylated by means of ketene without causing a measurable change in the specific virus activity or in the nature



C. A. Knight and J. A. Carlile

FIG. 14. DISEASED TURKISH TOBACCO LEAVES

AFFLICTED WITH DIFFERENT STRAINS OF TOBACCO MOSAIC VIRUS. T. M. V. = TOBACCO MOSAIC VIRUS. Y. A. = YELLOW AUCUBA MOSAIC VIRUS. G. A. = GREEN AUCUBA MOSAIC VIRUS. M. = A MASKED STRAIN OF TOBACCO MOSAIC VIRUS. THIS LEAF IS PRACTICALLY INDISTINGUISHABLE IN APPEARANCE FROM A NORMAL TURKISH TOBACCO LEAF, YET CONTAINS MUCH VIRUS.

of the disease produced in Turkish tobacco plants. Since it seems unlikely that the acetyl groups are removed on inoculation of the modified virus to plants, the fact that the virus produced in such plants contains the normal amount of amino nitrogen may be regarded as evidence that the modified virus actually brings about the production of normal or unmodified virus. Similar results have been obtained with virus modified by the introduction of about 3,000 phenylureido groups per molecule of virus by means of reaction with phenylisocyanate. These results demonstrate that a large portion of the surface structure of the virus may be changed without interfering with the basic reaction of virus reproduction. Other reactions are being studied in an effort to secure modifications that will be perpetuated in subsequent generations of the virus. The purposeful production of new and useful strains by chemical means is one of the major problems in the virus field and its solution will be of tremendous importance not only from a practical standpoint but also in connection with the larger and fundamental problem of the nature of virus activity. The latter problem, the inactivation problem and the problem of induced mutation are all so closely related that it is impossible to attack one without attacking the others and simultaneously fundamental problems in other fields, such as the origin of a cancerous cell, the duplication of a chromosome, the mutation of a gene, and even perhaps the nature of that ill-defined something called life.

Although we do not know how viruses originate, reproduce or mutate, we have learned much about their chemical properties during the past five years. We know that for every reasonably stable virus which has been investigated there is a definite, characteristic, high molecular weight material which is at least as complex as a nucleoprotein. The properties of these materials may differ widely, although in each instance the size, shape and chemical and other properties are the same regardless of the source of the virus. The properties of materials from strains of the same virus are similar

although slightly different. The amounts of the materials which may be obtained differ tremendously and appear to depend upon the host and the virus or virus strain. The materials appear to be reasonably homogeneous when carefully prepared. Many different types of experiments have demonstrated a direct correlation between the integrity of structure of a given material and its virus activity. Because of this and because it has not been found possible to separate virus activity from these materials, there is reason to believe that they are the viruses. They appear to have the properties of molecules and in addition the property of virus activity, a kind of property usually assigned to organisms and one which has not heretofore been ascribed to molecules. Some may wish to consider that there is a sharp line of division between molecules and organisms and that viruses belong wholly in one or the other of these two groups. Others may wish to retain the sharp line of division but place some viruses in one group and other viruses in the second group. However, to a chemist it appears preferable to consider that virus activity may be a property of molecules, that there may be no sharp line of division between molecules and organisms, and that the viruses may provide the transition between the two. One virus has been inactivated and reactivated, and some idea gained of the accompanying change in structure. Studies on the elementary composition, the amino acid distribution, the amount and kind of nucleic acid, the immunological reactions, the effect of different enzymes, the pH and thermal stability ranges, and the effect of many different kinds of chemicals have been completed on some of the viruses. Extensive studies of the physical properties have also been made and the existence of long range forces between molecules has been demonstrated. There is every reason to believe that the extension of these studies will eventually result in the solution of the more fundamental problems related to the viruses, such as the nature of their origin, reproduction and mutation.

THE CONTRIBUTIONS OF TECHNOLOGY

Scientists, engineers and inventors have created the so-called technological age. We believe that our work and its results are predominantly beneficial to mankind. Some timid souls are frightened at the pace with which technological achievements have come; some see our creations being put to destructive use in warfare and feel that man should not be allowed to have such powerful tools; still others worry about the unemployment that frequently results from introduction of labor-saving machinery or from replacement of one product by a superior one. We technologists, while admitting both accidental and premeditated harmful effects of science, nevertheless see the gains from technology as far outweighing the losses, and we have sure faith in the social value of our efforts.

We see such advances as improved homes, better wages, shorter hours of work, far less disease and suffering, free time for education during youth and for vacations during working years, and, finally, pensions in our old age. None of these happy situations ever existed in the history of the world for the masses of any people until science and its applications made them possible. Just for one illustration consider this tremendous fact: It has been estimated that during the past three hundred years the population of the earth has increased three times as much as in all the preceding hundreds of thousands of years of man's life on this earth. Knowledge of medicine, disease and health; more fruitful methods of agriculture; methods of fast communication and transportation have combined with other technological factors to push back the starvation, epidemics, infant mortality, floods and other hazards which were continually limiting the earth's population. Whether we like the fact or not, about 1,500,000,000 people are alive to-day who would be dead or unborn except for modern technological progress. Since that figure includes two or three out of every four persons among us, I imagine that if we were to vote on the subject, most of us would be in favor of keeping and further extending the technological progress that has made these things possible.—*Karl T. Compton, Technology Review, June, 1941.*

GEOLOGICAL ASPECTS OF OUR NATIONAL PARKS

II. PARKS ALONG THE CONTINENTAL DIVIDE AND EASTWARD

By Dr. RAYMOND E. JANSSEN

EVANSTON, ILLINOIS

National Parks of the Rockies

The great inland chain of the Rocky Mountains, carrying the continental divide along its crest, extends from the interior of Canada to New Mexico. Along its length have been established several national parks, both in the United States and in Canada. The present Rocky Mountains are the end products of a series of mountain-making movements which have affected the belt since the Paleozoic Era. The so-called "Ancestral Rockies" were elevated during the Paleozoic, and then brought low by erosion. A reelevation of the chain occurred during the late Mesozoic Era, and subsequent uplifts again took place during the Tertiary Period. The building of the Rockies was accompanied by great volcanic activity, with extensive lava flows and thick deposits of tuff and ashes being erupted in many places.

Foremost among our national parks is Yellowstone, first and largest in our park system. Established in 1872, Yellowstone has since been increased in area from time to time until it now contains 3,471 square miles of territory. The central portion of the park is a broad, volcanic plateau about 8,000 feet above sea-level. Round about are mountain ranges rising from 2,000 to 4,000 feet higher.

The volcanic outpourings which accompanied and followed the rise of the Rocky Mountains continued until comparatively recent times. They gave the park its broad outlines of form in which it is seen to-day, except in so far as these have been modified by subsequent erosion and denudation. Most of the older granitic and sedimentary rocks were buried beneath lava and volcanic ashes. These lavas issued from several craters in the Absaroka and Gallatin Ranges, as well as from Mount Washburn and Mount Sheridan in the interior of the park. The later flows, mostly of rhyolite, spread widely over the region, forming the park plateau. The rocks have a variety of textures, ranging from soft friable material which easily grinds to powder to the glassy structure of Obsidian Cliff. The very latest eruptions, however, were of basalt. These were small in extent as compared to the other rocks, but quite important from a scenic viewpoint.

Presumably, the park was almost entirely covered by a vast ice sheet during the Ice Age, for evidence of its work may be seen throughout the region. The huge granite boulder perched near the Canyon of the Yellowstone must have been brought there by ice, since its counterpart is not known within twenty miles. By plowing out valleys and lake basins, and rounding and smoothing elevations, ice has surpassed any other agent in giving the park its present topography.

The thermal activity in Yellowstone Park, for which it is most famously known, presumably dates from the last of the volcanic eruptions. It is known to antedate the glacial epoch, since glacial drift occurs on the top of Terrace Moun-

Photo by author

HARD BASALTIC LAYER

OVERLYING THE DECOMPOSED RHYOLITES OF THE YELLOWSTONE PLATEAU, AND STANDING OUT IN MANY PLACES AS A SHEER WALL.

Courtesy Chicago & North Western Railway

CHANGES IN SUBSURFACE STRUCTURE

IN YELLOWSTONE PARK ARE CONSTANTLY TAKING PLACE, WITH RESULTING CHANGES IN THERMAL ACTIVITY AT THE SURFACE. INCREASED ACTIVITY AT ROARING MOUNTAIN HAS RECENTLY DESTROYED PART OF THE FOREST.

tain, which is a hot springs formation. The present hot springs and geyser areas represent only a very small part of the former wide-spread thermal activity experienced by the region. Decomposition of volcanic rocks, caused by the action of steam and hot water, may be seen throughout the plateau. The beautiful coloring of Yellowstone Canyon is the result of such decomposition. Other areas of similar decomposition are evident in recent road cuts.

The thermal springs, which consist of both the eruptive geysers and non-eruptive hot springs, number about 3,000. Most of them are situated in the six principal geyser basins lying in the west and south central parts of the park.

Geysers are defined as periodically eruptive hot springs. They can occur only where high interior temperatures approach closely to the earth's surface. They must also possess a tube or "plumbing system" which is crooked or constricted in such a way as to prevent easy circulation of the water. The walls and cracks of this system must be made of silica or other rock which is strong enough to withstand the pressure and explosive action of steam. In operation, heat causes the water in the lower portion of the tube to expand to the extent that the cooler water above can no longer hold it down. The water then begins to bubble over, relieving the pressure of the superheated water below. The release of pressure immediately allows the superheated water to flash into steam, thereby causing the eruption. After the tube again fills with water, the process is repeated.

Since the subsurface system of each geyser differs somewhat, there is wide variation in their activity, dependent largely upon the length of time required for their respective tubes to refill and the water to become heated. In the case of Old Faithful, the refilling is quite constant so that eruptions are repeated at quite regular intervals. In other cases,

refilling may be much less constant because of factors involving rainfall and general subsurface seepage so that the eruptive periods may be separated by days, weeks, or months. Many of the bubbling hot springs which throw water a few feet into the air every few minutes are really tiny geysers.

Changes in the subsurface structure of the thermal areas are always taking place. Consequently, some geysers and hot springs which have been in existence for a long time may suddenly cease to function. On the other hand, new ones may appear just as suddenly. Mammoth Hot Springs, one of the outstanding features of the park since its discovery, has been drying up during recent years. At Roaring Mountain, however, thermal activity has been increasing to the extent that wooded areas in the vicinity have had the trees killed by the heat and overflowing water.

Although the thermal activity of Yellowstone Park fires the imagination, and spreads its fame around the world, much of the geological romance of the park really centers in Yellowstone Lake. Although once flowing into the Pacific, the lake waters now enter the Atlantic, thereby having caused a shift in the location of the continental divide. At present the waters of Yellowstone Lake overflow northwardly through Yellowstone Canyon, eventually reaching the Missouri River in northeastern Montana.

Originally, the level of Yellowstone Lake was 160 feet higher than at present. At that time its waters drained southwestwardly into the Snake River, which crosses the southern part of the park, eventually reaching the Columbia River and the Pacific Ocean. There was then no Yellowstone Canyon or Falls, their location being covered by a northward extension of the then larger lake. Just north of the lake, a low divide carried the continental divide. A small stream, called Sulphur Creek, working headwardly toward the top of this divide, eventually tapped the waters of the lake, thereby establishing a new outlet. The main channel of this stream then became the lower Yellowstone River, and subsequent deepening by the river carved Yellowstone Canyon. The Upper and Lower Falls within the canyon are caused by two hard rock dikes which cut across the softer, decomposed rocks of the plateau. As a result of this diversion of the Yellowstone Lake waters through the canyon, and the consequent lowering of the

Courtesy Northern Pacific Railway

GEYSER BASINS OF YELLOWSTONE PARK SHOW EVIDENCE OF HOT ROCKS CLOSELY BENEATH THE SURFACE. THESE INDICATE DYING VOLCANIC ACTIVITY. MANY OF THE GEYSERS AND STEAM VENTS ARE SITUATED IN CLOSE PROXIMITY TO COLD SURFACE WATERS.

Courtesy Great Northern Railway

FOLDED AND CRUMPLED ROCKS IN GLACIER NATIONAL PARK

BEARING EVIDENCE OF THE MIGHTY PRESSURES WHICH CONTORTED THE ANCIENT STRATA. AT THE LEFT, WITH ITS CONCENTRIC CREEP MARKS, MAY BE SEEN THE LOWER TERMINUS OF A GLACIER.

Courtesy U. S. Department of the Interior

MANY GLACIER REGION OF GLACIER NATIONAL PARK

UPPER SAINT MARY'S LAKE, SHOWING CITADEL AND FUSILADE MOUNTAINS. THE EFFECTS OF GLACIATION UPON TOPOGRAPHY ARE VIVIDLY SEEN. NOTE THE U-SHAPE OF THE VALLEY.

lake level, the former southern outlet ceased to function, thereby causing the continental divide to shift to the opposite side of the lake.

Just south of Yellowstone Park, extending along the western border of Wyoming, rises the jagged Teton Range. Grand Teton National Park, established in 1929, contains an area of 150 square miles.

The Grand Tetons, which are among the most rugged mountains of America, are an impressive example of block-faulting. The range has its origin in the later periods. These are topped by young beds of lava which are continuous with those of eastern Idaho and the Yellowstone Park plateau.

The isolated peaks, the knife-like ridges, the precipitous canyons and the polished rock floors which characterize the range are largely the results of glaciation of the Ice Age. A few of the glaciers still remain near the summits, but others have vanished. They have left in their places beautiful cirques and picturesque alpine lakes. As the former glaciers reached the valley floor, they

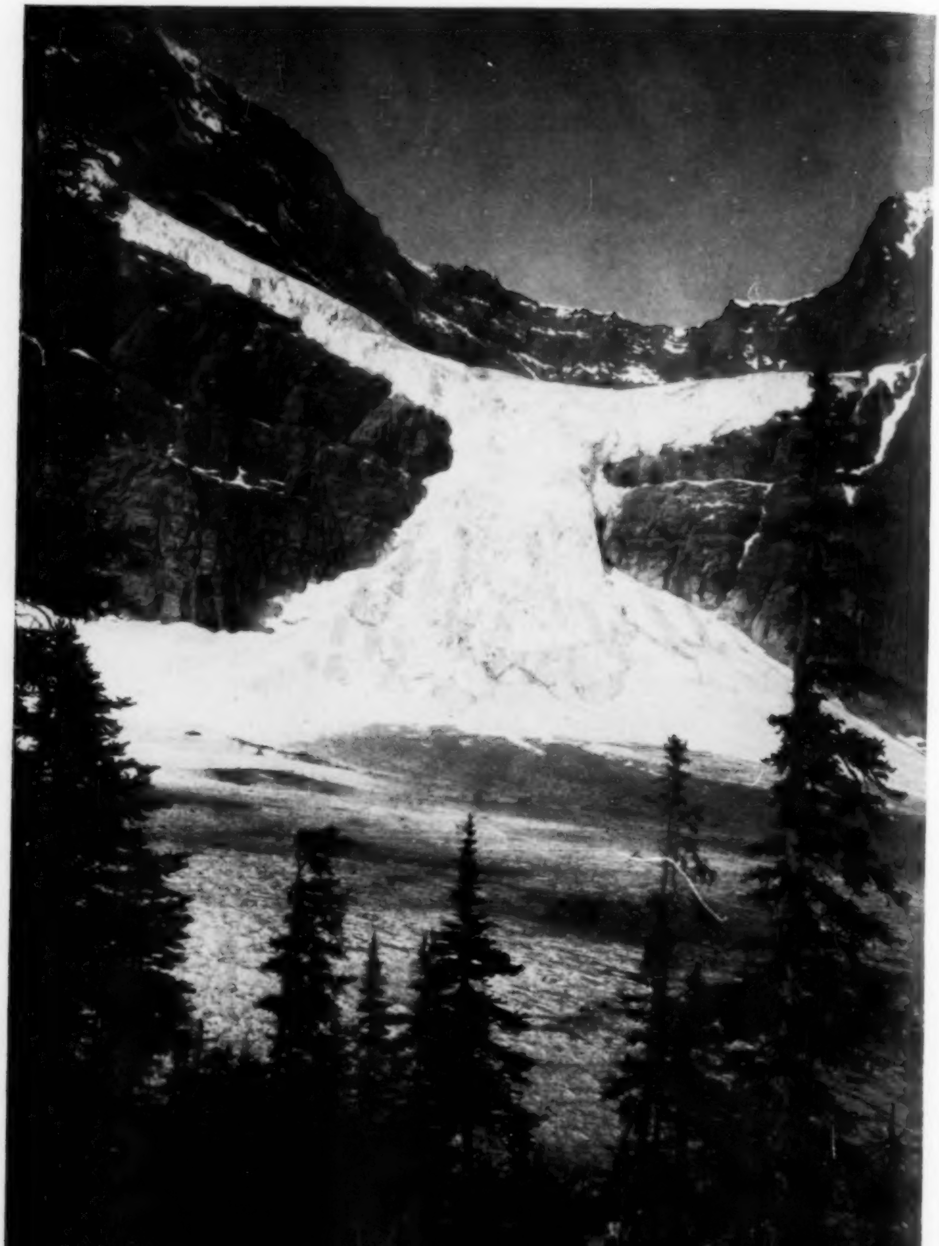
Courtesy U. S. Department of the Interior

THE GRAND TETON RANGE PRESENTS A RUGGED FRONT TO THE EASTWARD

IT IS CUT INTO MANY JAGGED SEGMENTS BY FORMER GLACIERS. NUMEROUS MORAINES ENCLOSE THE CHAIN OF MANY LAKES WHICH LIE AT THE FOOT OF THE MOUNTAINS.

Rocky Mountain uplift which began at the close of the Mesozoic Era and continued into the Tertiary Period. The eastern face of the range is an enormous fault scarp along which a great block, forty miles long, was uplifted and tilted westwardly. The total amount of uplift along the eastern side of this block approximated 10,000 feet, or more. Viewed from the east, one sees the precipitous side of this block, made up largely of very ancient, uplifted pre-Cambrian crystalline rocks. On the west flank are overlying stratified rocks of dropped their loads of rock material in morainic dams behind which were impounded the waters of Jenny Lake, Taggert Lake, Jackson Lake and others which line the valley along the Teton front. The wide valley floor, known as Jackson Hole, is an outwash plain, strewn with the gravels which were deposited there by the streams of melting ice water.

The effects of glaciation, as well as mountain faulting, are exemplified to much greater degrees in Glacier National Park. Glacier Park, occupying 1,538



Courtesy Chicago & North Western Railway

LIKE A FROZEN WATERFALL, A GLACIER POURS ITS ICE OVER A CLIFF
REFORMING AS A "RECONSTRUCTED GLACIER" BELOW.

square miles of our northern Rockies, represents the American section of Waterton-Glacier International Peace Park, established by joint action of Congress and the Canadian Parliament in 1932.

The Rocky Mountain Front in this region, like that of the Tetons, consists of an enormous fault extending for many degrees of latitude across Montana and Alberta. The faulting here, however, not only elevated the rocks vertically, but also thrust them eastward horizontally so that they overlapped strata of much younger age. This overthrust faulting was of such proportions that it carried deep-seated rocks of Proterozoic age up and over on top of Cretaceous rocks for a horizontal displacement of at least fifteen miles, making this one of the greatest overthrusts known. This action occurred during the Rocky Mountain uplift; hence it involved not only the very ancient Proterozoic rocks, but also all the overlying Paleozoic and Mesozoic strata of the region. Subsequent erosion has removed most of these overlying strata along the eastern front, however, thereby exposing the Proterozoic rocks resting on top of Cretaceous rocks which are some 500,000,000 years younger. Chief Mountain, on the eastern border of Glacier Park, is a detached block of overthrust Proterozoic rock lying on top of the Cretaceous plain. Similar relationships of the rocks may be seen in Swiftcurrent, St. Mary and Cutbank valleys.

The massive continental glacier, moving down from the North, overrode the uplifted mountains of Glacier Park, carving them to an extent not paralleled in any of our other national parks. As a consequence, there now are precipitous cliffs four and five thousand feet high, enormous U-shaped valleys once the channels of glaciers, knife-like edges on high divides, hundreds of cirques and glacial lakes and thousands of tiny streamlets trickling down from the sixty glaciers which still remain as remnants of a once more extensive ice cover. Individually, the glaciers of Mount Rainier surpass those of Glacier Park, but the phenomena of former glaciation in all its multiplicity is best revealed in the intricate sculpturing of the Rockies in Glacier National Park.

Courtesy Great Northern Railway

MELTED GLACIER

GLACIER SIMILAR TO THAT ON OPPOSITE PAGE HAS LONG SINCE MELTED AWAY, LEAVING TWO LAKES, ONE ABOVE AND ONE BELOW THE PRECIPITOUS CLIFF.

The Rocky Mountain System, which comprises many ranges, reaches its climax of altitude in Colorado. The state contains 765 peaks which attain an altitude of more than 11,000 feet. Of these, 45 exceed 14,000 feet in height. Mount Elbert, 14,420 feet in altitude, is exceeded in height within the United States only by Mount Whitney in Cali-

Courtesy Chicago, Burlington & Quincy Railroad

MASSIVE SUMMITS OF COLORADO ROCKIES RISE IN CRAGGY RELIEF

THROUGHOUT ROCKY MOUNTAIN NATIONAL PARK, EXTENDING ENDLESSLY ACROSS THE HORIZON. NOTE THE BOWL-SHAPED CIRQUES AND U-SHAPED VALES WHICH INDICATE FORMER GLACIERS.

fornia, which is merely 75 feet higher. About one seventh of Colorado exceeds 10,000 feet in altitude.

In such a setting as this has been established Rocky Mountain National Park, occupying a portion of the Front, or Snowy, Range of the southern Rockies. Containing 405 square miles of area, the park itself represents only a small portion of this extensive mountain system. Of the four national parks situated in the Rocky Mountain Chain, only this one exhibits in marked degree the true characteristics of the chain's internal structure. The rocks here are prevailingly granite, upwelled during the Rocky Mountain revolution, subsequently uncovered by erosion in a fashion comparable to the granitic scenery of the Pacific Chain. Dominated by Long's Peak (14,255 feet high) the Front Range presents a long, majestic face to the east where it overlooks the broad expanse of the Great Plains. Originally, Long's Peak and the adjacent peaks, which are nearly as high, were a single mountain. Erosion and glaciation have cut deep valleys, baring the granite core and slicing the range into distinct segments. The east side of Long's Peak is a sheer precipice of 1,200 feet, beneath which is glacial Chasm Lake, held in place by a morainic dam. Although the legible record of Ice Age glaciation here is most distinct, it does not equal the vivid records so profoundly displayed in Glacier Park. For sheer mountain massiveness with its endless array of peaks in range after range, Rocky Mountain Park, however, exhibits the finest example of the continental mountain structure in our national park system.

Mountain Parks of the East

Far older in age than any of our western mountains are those which lie east

of the Mississippi. Here several national parks have been established. Three of these, Acadia, Shenandoah and Great Smoky Mountains national parks, are situated in the Appalachian belt.

The Appalachian Mountains themselves were preceded in point of time by another series of ranges, called the Acadian Mountain System, which extended through the maritime provinces of Canada, New England and along the coastal region as far south as Virginia. The building of the Acadian Mountains occurred at the close of the Devonian Period, following which they were worn low by erosion. At a much later time, recurring earth movements along this belt at the close of the Paleozoic Era gave birth to the Appalachians. Extending from Newfoundland to Alabama, the Appalachian Mountains were then comparable in height and grandeur to the present ones of the West. They were worn low during the succeeding Mesozoic Era to a more or less level peneplain in which the hard and soft rocks of the folded mountains were beveled off alike. At the close of the Mesozoic, this low peneplain was reelevated to new heights.

Ever since that time, erosion has continued to dissect this uplifted belt, culminating in the present configuration of the ancient structures. Where less resistant rocks were at the surface, valleys came into prominence; where harder rocks formed the surface, the old peneplain level is still preserved. As one stands upon the crest of these eroded mountains and looks out across the panorama of hills and vales, he can not fail to be impressed with the common level of all the higher elevations. The old peneplain is there, etched against the horizon and dissected only by the valleys which have been worn in the ancient rocks.

It is for these far-reaching views across the old peneplain that Shenandoah and Great Smoky Mountains parks are noted. An appreciation of this geologic history may be obtained by traveling along Skyline Drive, which extends for a distance of nearly 100 miles along the crest of the Blue Ridge Mountains in Shenandoah National Park. Along this parkway, one may search in vain for signs of glaciation. No U-shaped valleys, no moraines, no cirques nor glacial lakes exist. It is stream erosion alone which has shaped these ancient mountains.

Glaciation, however, has produced the configuration of our easternmost national park—Acadia—located on Mount Desert Island off the coast of Maine. The island is deeply indented by numerous bays and inlets, one of which nearly cuts the island in half. This inlet, called Somes Sound, is a fiord or glacial estuary, the only one along our Atlantic coast south of Newfoundland. It had its origin as a glaciated valley during the Ice Age. Sinking of the shoreline following the gouging of the valley produced the fiord. It

Courtesy Chicago, Burlington & Quincy R.R.

EASTERN SIDE OF LONG'S PEAK

SOURCE OF A GLACIER WHICH PLUCKED AWAY THE MASSIVE GRANITE CORE OF THE MOUNTAIN, FORMING A SHEER PRECIPICE OF 1,200 FEET.

Photo by author

THE NEARLY LEVEL SUMMITS OF THE APPALACHIAN MOUNTAINS

THESE LEVEL SUMMITS MARK THE SURFACE OF AN ANCIENT PLAIN WHICH HAS BEEN UPLIFTED AND SINCE DISSECTED BY STREAM EROSION.

is comparable in origin to those along the coast of Norway.

Except for the effects of glaciation and the subsidence of the region, the geological history of Acadia National Park is associated with the Acadian and Appalachian uplifts. Here the mountains are believed to have once reached elevations of at least 15,000 feet; but if so, they have since been worn so low that only the ancient granitic core now remains. Along this rock-bound coast of Maine, we may view a geologic epic wherein the sea emerges triumphant in its age-long conflict against the land.

Having no connection whatever with the Appalachian Mountain System is Isle Royale National Park in Lake Superior, established in 1940. Although quite young as a national park, it is most ancient in origin. With a land area of more than 200 square miles, Isle Royale Park consists of one large island and an archipelago of many smaller islets. Rising only slightly above the waters of Lake Superior, the land surface of Isle Royale can not now be considered as mountainous, although it might well have been so in the past.

The rocks forming Isle Royale are of Proterozoic age, and hence are comparable in time of origin with the lowermost strata which rest on the ancient granites at the bottom of the Grand Canyon. That volcanic activity was most pronounced at this time in the Lake Superior region is evidenced by the many lava flows which have here been piled successively upon each other. What happened to these lava rocks of Isle Royale during the half billion years or more of elapsed time since their formation until the coming of the ice sheets is largely a lost chapter in their geologic history. All evidence was swept away when the ice completely overrode the Great Lakes region. The topography of Isle Royale, as we see it to-day, is essen-

tially the same as it was left after the recession of the last ice sheet.

The Subterranean Parks

The profound effects of running water may not only be appreciated in the mighty canyons which cut the surface of our lands, but also in the extensive subterranean caverns which have been hollowed out within the rock formations below the surface. Simply stated, caverns are joints or cracks which have been greatly enlarged by the solution action of the ground water passing through them. Large caverns are developed only in soluble rocks, principally in limestones, dolomites and gypsum, and sometimes in salt. Water moving through such strata makes its way along the joints, gradually enlarging them by solution and usually collecting in underground streams. These streams, some of which are quite large, join the surface drainage of the region either by flowing out of the caverns or by underground passages. Many large springs are nothing more than underground streams which have passed through caverns and emerged upon the surface.

The material dissolved by the underground waters is eventually carried to the surface rivers and thence out to sea, or else deposited again en route. When this ground water becomes saturated with mineral matter, slight changes may cause deposition of some of the material. One of the most common causes is the loss of carbon dioxide from the water. When highly charged water slowly drips from the roof of a cavern, loss of carbon dioxide occurs, and some of the dissolved mineral matter may then be precipitated. This gives rise to beautiful cave formations such as stalactites, stalagmites, pillars and onyx draperies. Thus the process of dissolution may give way to

Courtesy U. S. Department of the Interior

THE ROCKBOUND COAST OF ACADIA NATIONAL PARK

FORMED BY THE SUBSIDENCE OF AN OLD ERODED LAND SURFACE WHICH TURNED MANY OF ITS LOWER STREAM COURSES INTO BAYS, ESTUARIES AND SMALL ARMS OF THE SEA.

Courtesy Santa Fe Railway

MAGNIFICENT CAVE FORMATIONS IN CARLSBAD CAVERNS

BUILT BY DRIPPING WATERS, CHARGED WITH CALCIUM CARBONATE. STALACTITES, LIKE ICICLES, GROW DOWNWARD FROM THE CEILINGS. DROPS OF WATER WHICH SPLASH UPON THE FLOORS BUILD UP CONE-LIKE STALAGMITES. SOMETIMES A STALACTITE AND STALAGMITE WILL JOIN TO FORM A PILLAR, AND CONTINUED TRICKLING OF WATER DOWN ITS SIDE MAY INCREASE ITS BULK AND VARY ITS CONFIGURATION.

that of deposition in the previously hollowed caverns.

Three large underground caverns—Wind Cave in the Black Hills region of South Dakota, Mammoth Cave in Kentucky and Carlsbad Caverns in New Mexico—have been incorporated into our national park system. Wind Cave received its name by virtue of its discovery through a strange whistling sound caused by air escaping from a small hole in the ground. This current of air, which alternately moves in and out of the cavern, is apparently caused by differences in atmospheric pressure outside. When the barometer is falling, the current moves outward; when the barometer rises, the current blows inward. This hole, only ten inches in diameter, is the only known natural surface opening to the cavern.

The interior of the cavern, reached by a specially constructed entrance and elevator, is noted for its crystal formations known as frostwork and boxwork. The frostwork consists of tiny white crystals on a tan or pink background and hang like frost upon the ceilings and ledges. The boxwork consists of fin-like projections of calcite which hang from the ceiling in a sort of honeycomb pattern. This boxwork is a depositional feature peculiar to Wind Cave.

The famous Mammoth Cave of Kentucky has been set aside for protection by the National Park Service, but will not obtain full park status until some 45,000 acres have been deeded to the government. At present, nearly 43,000 acres have been acquired. Mammoth Cave has become so well known since its discovery in 1799 that it requires little description. Its many ramifications, of which nearly 200 miles of avenues have been explored, are only part of an extensive network of subterranean passages which have been formed in the Lower Carboniferous limestones of the Mississippi Valley.

These limestones were laid down at the bottom of a sea which then covered a vast part of the North American continent, extending from the Arctic to the Gulf of Mexico. Eventually the region was elevated above the sea, and since the close of the Paleozoic Era the Mammoth Cave area is believed to have remained dry land. Consequently, there has been

Courtesy Santa Fe Railway

ENTRANCE TO CARLSBAD CAVERNS

IN THE SEMI-DESERT FOOTHILLS OF THE GUADALUPE MOUNTAINS IS AN UNPRETENTIOUS OPENING WHICH LEADS TO THE MOST EXPANSIVE UNDERGROUND WONDERLAND OF THE EXPLORED WORLD. BATS, MOVING IN AND OUT OF THIS OPENING, ATTRACTED ATTENTION WHICH LED TO THE DISCOVERY OF CARLSBAD CAVERNS.

adequate time for the percolating ground waters to dissolve out the massive caverns during the more than 200,000,000 years which have since elapsed.

Of unusual magnificence and extent are the underground passages constituting Carlsbad Caverns National Park in the foothills of the Guadalupe Mountains of New Mexico. The Guadalupe Mountains are outliers of the Rockies farther north. The limestone in which the cav-

erns have been formed is slightly younger in age than that of Mammoth Cave, having been laid down during the Permian Period, immediately following the Carboniferous. The earth movements which raised the Rocky Mountains also raised the Carlsbad area—some 60,000,000 years ago. Since then, underground waters have hollowed out the enormous caverns and refilled them partially with the beautiful formations which are unique to underground passages.

Although recognized as the greatest underground labyrinth yet discovered, the extent to which the caverns may penetrate beneath the Guadalupe Mountains is not yet known. Since the discovery of the caverns in 1901, three general levels of passageways have been located. The first of these is 750 feet below the surface, and is the level to which visitors are conducted by elevator. Below this is another vast level at 900 feet, and a third at 1,320 feet. None of these has been completely explored, and additional levels may also exist.

About seven miles of passageways have been developed and opened to visitors. The largest of the passageways, called the Big Room, is about 4,000 feet long, 625 feet wide, and at the highest point the ceiling arches 350 feet above the floor. Such an excavation indicates an enormous power of dissolution and removal by underground waters. Within this room, the formations which were later deposited are massive as well as magnificent. In size, the stalactites, stalagmites and fluted columns vary from pencil-like structures to those approximating the dimensions of giant trees. Here human comprehension seems to become lost in a maze of fantasy, for one finds it difficult to believe that so vast and magnificent a spectacle could have been formed merely through the agency of little trickles of water. Carlsbad is to the subterranean world what the Grand Canyon is to the surface.

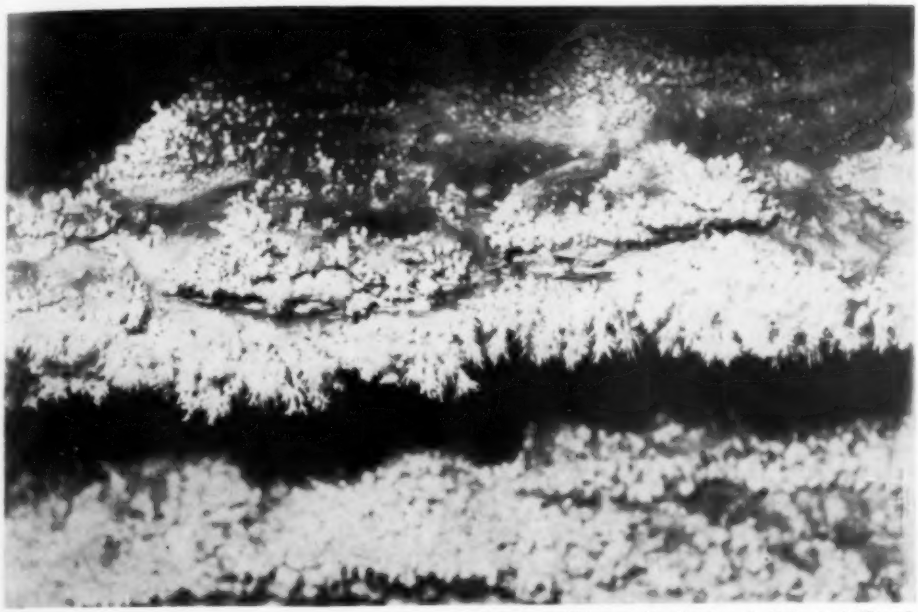
The Mineral Springs Parks

Two minor national parks deserve consideration because they contain mineral springs of therapeutic value. These are Hot Springs National Park, in the southern Ozark Mountains of Arkansas, and Platt National Park, in the Arbuckle Mountain region of southern Oklahoma.

Hot Springs became a national park in 1921, but it had been set aside as a government reservation as early as 1832. In a sense, this 1½ mile area might be considered as our first national park, although Yellowstone was really first established and administered as such. The springs themselves, of which there are 47, were famous for their therapeutic value before the white man discovered them. There is some indication that they gave rise to the rumor which brought Ponce de Leon from Spain in search of the Fountain of Youth. Indian tradition maintains that the springs were always considered as neutral territory by the warring tribes. The waters of the several thermal springs, which are practically identical in chemical composition, are now impounded in reservoirs, and all bath-houses receive the same water. Temperature of the water is always over 140° F.

Platt National Park, with an area of only 1⅓ square miles, and established in 1906, contains 32 springs of major importance. Of these, 18 are classified as sulfur, 6 as fresh water, 4 as iron and 3 as bromide. The latter are the only known natural bromide springs.

The rocks exposed in both parks are composed of sediments laid down beneath a former sea during early and middle Paleozoic times. Later, during the Great Coal Age, this region was folded and buckled into mountain ridges, with numerous faults, or breaks, permitting slippage along the lines of greatest strain. The mountains thus formed were later nearly leveled by erosion, but



Courtesy Chicago, Burlington & Quincy Railroad

FROSTWORK FORMATIONS OF PURE WHITE CALCITE
ADORN THE CEILINGS AND LEDGES OF WIND CAVE.

subsequent uplifts during the Appalachian and Rocky Mountain revolutions also elevated this region to new heights. Subsequent erosion has finally produced the present topography. The springs issue from fractures in the rocks, primarily along the old fault lines.

Several theories have been advanced as to the mechanism of the thermal springs. Most generally accepted is the meteoric theory which suggests that rain-water seeps downward along the slope of the formations and becomes confined between impervious layers. Eventually it finds outlet along the fractures or faults in the strata. Somewhere along its underground path it becomes heated by passing near a mass of uncooled rock. Another theory suggests that the water from the hot springs does not originate from rain seepage, but comes solely from the earth's interior. Such water, called juvenile water, escapes from molten rock as it cools, and thence finds its way to the surface. Other theories presume that chemical reactions or radioactivity in the rocks causes the heat which warms the waters. Regardless of the source of the heat and the water, the flow at Hot Springs National Park remains almost constantly at 1,000,000 gallons daily.

Our National Park System

The original motive in establishing national parks was that of conservation. The reservation of Hot Springs in 1832, and of Yellowstone in 1872, was for the prime purpose of protecting these areas from exploitation. That purpose still remains, but with the passing of the years, perspectives have broadened. The park system now also aims to portray by striking examples the great truths of natural science and the progress of civilization upon the continent.

The National Park Service was created in 1916, when it assumed supervision of the 16 national parks and 21 national monuments then under the control of the Department of the Interior. Our national park system really had its

Courtesy Chicago, Burlington & Quincy Railroad

A PECULIAR BOXWORK FORMATION OF CALCITE

FOUND ONLY IN WIND CAVE, WHICH ASSUMES A HONEYCOMB ASPECT UPON THE CEILINGS.

birth around a campfire, the site of which is still preserved in Yellowstone. The Washburn-Langford-Doane Expedition in 1869, the first scientific expedition to investigate the Yellowstone region, advanced the idea which led to the establishment of the first national park.

To-day our national parks are scattered through nineteen states and two territories. They extend from Maine to Hawaii, and from Alaska to Mexico. These parks occupy more than 10,320,000 acres of land. If the area of the national monuments and historical parks is added, the total acreage is more than doubled. More than 16,740,000 persons visited our national parks and monuments in 1940, the 26 national parks here considered attracting nearly half of these. That interest in our national reservations is increasing steadily is indicated by the fact that the total attendance for all units during 1933 was less than 3,500,000 persons. The most popular national park is Shenandoah, which registered nearly a million visitors last year.

Although our national parks include regions of the most diversified scenic grandeur of the world, they also contain many of the most complete records of the earth's long and eventful history. From the ancient granites at the bottom of the Grand Canyon to the glistening glaciers on the peak of Mount McKinley, is recorded in startling clarity the age-long story of an ever-changing world. Here, too, we may see in action the mighty geologic processes which have fashioned our lands.

Our great natural wonders are not, in any sense, completed. They are still in process of formation and evolution. Some day the last of Yellowstone's geysers will cease to erupt, and the last lofty glacier may melt away; but no person now living will witness these events. And again, new landscapes and new wonders will come into being.

RELATIVES AND HUMAN GENETIC ANALYSIS

By Dr. C. W. COTTERMAN

LABORATORY OF VERTEBRATE GENETICS, UNIVERSITY OF MICHIGAN*

In laboratories and clinics where research work is being conducted in human biology and medicine an increased interest is being shown in the study of relatives. As soon as this happens the research can, of course, be described as genetical. Now close relatives can often be secured with little extra effort, whereas the compilation of extensive family histories—the traditional approach—may be quite beyond the facilities of the research. This suggests that an even greater interest in human heredity might be manifested were the following facts more widely known.

Genetics could be defined as the study of the consequences of biological relationship, and we might therefore expect that *any* kind of relationship would provide *some* information about inheritance. Equally, we should expect that the closest relatives would be by far the most useful to the geneticist. Logical though these statements might appear, their full significance may not always be appreciated. For it is not uncommon to hear the view expressed that in order to offset the lack of experimental opportunities it is necessary in the study of human genetics to obtain very long and extensive pedigrees. Such pedigrees are indeed often very instructive, but for most genetical purposes they are certainly not essential and, in fact, may be considerably less useful than smaller units. In any event, the clinical investigator need not be daunted should he find it inconvenient or impossible to examine distant relatives.

The human geneticist is now provided with a variety of statistical procedures which have been specially devised for the peculiar conditions under which human heredity must be studied. These methods are designed to make use of data which appear very fragmentary and heterogeneous in contrast to the data of the experimental geneticist. Many of the techniques require only single families or even parts of families—pairs of brother and sister or parent and child. Some of the mathematical possibilities in this direction are indeed rather surprising. But at the present time, and probably for some time to come, most genetical data on man will be assembled by medical and other workers who are not directly concerned with its genetic analysis. Consequently there is some fear that many kinds of observations may be discarded unless it is realized that the appropriate analytical methods are available.

The mere realization of these opportunities, however, is not quite sufficient, for unless certain precautions are taken in recording the information the data will frequently be very misleading and therefore worse than useless. Practical suggestions for the clinical worker who wishes to safeguard his observations from this fate have been made available in excellent form by Roberts,[1] Macklin[2] and others. No special effort will be made here to call attention to these points; nor will the article deal with the aforementioned mathematical methods. It will rather attempt to summarize an intermediate ground—the genetical consequences of various kinds of relationship and the opportunities which they afford for special types of genetic analysis.

* Investigations in human heredity at the University of Michigan are supported by The Horace H. Rackham School of Graduate Studies.

1 J. A. Fraser Roberts, "An Introduction to Medical Genetics." Oxford. 1940.

2 M. T. Macklin, SCI. MONTHLY, 51 (1): 56, 1941.

Relatives—Kind and Degree

Genetically considered, there are only two *kinds* of relatives, provided we ignore the possibilities of inbreeding. These two kinds of relationship, which we shall term *unilineal* (A) and *bilineal* (B), are illustrated in Fig. 1, which makes use of the customary arrow diagrams. In each diagram the relatives in question are the two indicated by blackened circles. Each individual is connected to his parents by the two lines

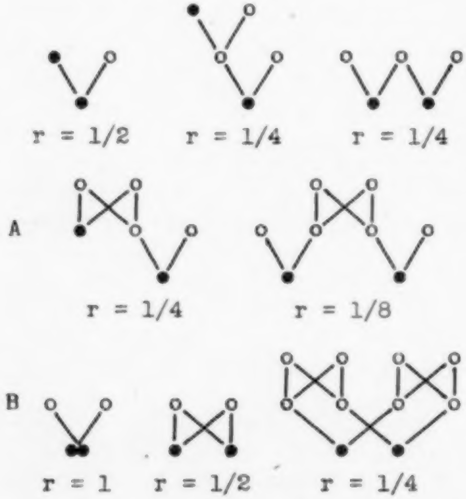


Fig. 1.

which lead upwards. It is then easy to see that the examples of A-relatives depicted are, in order, parent-child, grandparent-child, half sibs,[2a] uncle-nephew and single first cousins. The B-relatives represent one-egg or "identical" twins, full sibs and double first cousins.

In each example the symbol r denotes the *degree*, or coefficient, of relationship, as devised by Professor Wright.[3] Numerically, it can always be found by taking ($\frac{1}{2}$) to the power of the number of links in a path of descent connecting the two relatives and summing such terms for all possible paths. Genetically, r is the probability that, for any (autosomal) gene specified in the one individual, the relative will possess the *same* gene—same in the sense of common origin. It may also be interpreted as the most likely fraction of *all* genes to be shared by the two relatives.

The two kinds of relatives, A and B, are differentiated by the fact that only in the case of B-relatives are there two paths of which all links are separate or independent. This means that it is impossible for A-relatives to share both genes of a pair; but not so for B-relatives. More exactly, if we denote by A_0, A_1, A_2, A_{12} the probabilities that neither, the one, the other, or both genes of a pair will be shared by A-relatives, and similarly for B, we find, for any degree of relationship, r, the following conditions:

$$
\begin{array}{ll}
A_0 = 1 - 2r & B_0 = (1-r)^2 \\
A_1 = r & B_1 = r(1-r) \\
A_2 = r & B_2 = r(1-r) \\
A_{12} = 0 & B_{12} = r^2
\end{array}
$$

Thus, for half sibs, $A_0 = \frac{1}{2}$, $A_1 = A_2 = \frac{1}{4}$, $A_{12} = 0$; for double first cousins, $B_0 = 9/16$, $B_1 = B_2 = 3/16$, $B_{12} = 1/16$; and so on. It will be noted that, in accordance with the definition of r, we always have $A_1 + A_{12} = r$ and $B_1 + B_{12} = r$.

We may now discuss some of the advantages of bilineal relatives. Whatever these advantages might be, we should expect them to arise from the fact that B_{12}, unlike A_{12}, is not zero.

The formation of one-egg twins is, of course, an asexual process, but genetically such twins can be regarded as B-relatives of degree $r = 1$, for we then have the familiar fact that their gene-pairs must be identical throughout: $B_{12} = r^2 = 1$. The advantages afforded by this unique relationship need hardly be dwelt upon here. By possessing pairs of genetically uniform subjects we of course greatly simplify the problem of assessing the relative influence of heredity and

[2a] In genetics "sibs" are children (male or female), of the same parents; "half sibs" are children having only one parent in common.

[3] Sewall Wright, *Amer. Naturalist*, 56: 330, 1922.

environment. It is interesting to note, however, that having $r=1$ is, in a sense, carrying a good thing too far. For, since there can be no genetic variation at all, "identical" twins can not in themselves afford any information as to the *mode* of inheritance; their value lies rather in demonstrating the *fact* of inheritance. But certainly, whatever the nature of the genetic study, the investigator should make full use of multiple births and might well undertake a special search for them. In interpreting the data he must of course first decide which of his pairs are of one-egg and which of two-egg origin. This diagnosis, as well as methods of nature-nurture analysis, is discussed by Dr. Newman[4] in a recent book in the American Association for the Advancement of Science Series of non-technical books.

Full brothers and sisters are B-relatives of degree $r=\frac{1}{2}$, and we therefore have $B_0=B_1=B_2=B_{12}=\frac{1}{4}$. This explains the facts observed in human pedigrees which involve *recessive* abnormalities. By definition, a recessive gene is one which is required to be present in double dose in order to produce a detectable change. Let us now consider any defective individual who possesses two such genes. If the gene is quite rare in the population, then we may assume that if any of his relatives are affected at all they will be so by virtue of sharing the *same* two defective genes. Now $A_{12}=0$, but $B_{12}=r^2$. Hence we do not expect the parents, or children, or in fact any of the A-relatives to be affected, but we always expect one fourth of the brothers and sisters to be affected. Hereditary abnormalities of this sort are therefore sometimes called *familial* diseases; they are likely to occur in the sibship, especially if it is a large sibship, but will usually be absent in the patient's near ancestors or descendants. In studying traits suspected of being recessive in inheritance the clinician will, of course, do well to specialize on the sibs of his patients.

Another kind of genetic study which depends largely on the comparison of sibs is the investigation of *genetic linkage*, the location of two or more gene-sets in the same chromosome. The main statistical effect of this phenomenon is the production of a two-way intrafamilial correlation. That is to say, in some families there is a positive, in others a zero, in still others a negative correlation between the grades of the two characters. The over-all correlation is therefore likely to be zero. These generalizations were first clearly brought to light in the studies of Dr. Penrose,[5] who developed special statistical tests for the detection of linkage in data consisting of sibships of unspecified parentage. In this connection Professor Fisher[6] has shown that lack of information about the parents need only entail a loss of 13 per cent. of the precision secured by the examination of children and parents combined. This surprising result furnishes a good illustration of the fact that the study of heredity need not concern itself with the comparison of ancestor and descendent.

Sibs also present certain practical advantages which must not be overlooked. Compared with other sets of relatives they will usually be less variable in age and will probably have been exposed to more nearly similar environments. Moreover, up to a certain age the entire sibship will usually be available as a unit for examination. In certain kinds of studies it may be possible to exercise some selection of cases, and it is then useful to know that the precision or amount of information provided by a sibship is usually an accelerating function of its size. In several kinds of analysis it is found that the amount of information furnished by a sibship of s members is proportional to $\frac{1}{2}s(s-1)$, this being

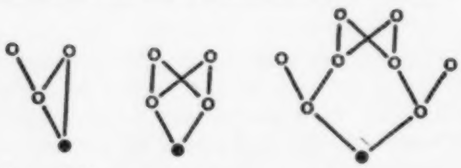
[4] H. H. Newman, "Multiple Human Births," New York: Doubleday-Doran. 1940.

[5] L. S. Penrose, *Ann. Eugen.*, 6: 133, 1935; *ibid.*, 8: 233, 1938.

[6] R. A. Fisher, *ibid.*, 6: 339. 1935.

the number of sib-pair comparisons which can be made. Thus, in such studies, single-child families are worthless, a fraternity of 5 gives 10 times the information of a fraternity of 2, and a fraternity of 8 is worth 28 times as much.

As we have just seen, some very valuable information can be obtained from data of even a single generation. Actually, certain genetic phenomena can be investigated without studying any relatives whatsoever. This is well known to the physician who inquires from the patient concerning the possibility of consanguinity in the parents. Fig. 2 shows the offspring of three different consanguineous matings: parent-child, brother-



i = 1/4 i = 1/4 i = 1/16

FIG. 2.

sister and single first cousins. In each case i represents the coefficient of inbreeding[7] of the resulting child. This is simply half the coefficient of relationship, r, of the parents, and gives, for any particular gene-pair, the probability that both genes were derived from a single gene present in one of the ancestors common to both parents. Inbreeding is therefore of significance in connection with recessive inheritance. If the incidence of some rare recessive disease is q^2, then the probability that an inbred individual of degree i will receive two such genes and therefore show the defect is $iq + (1-i)q^2$. Thus, for a recessive defect appearing in 1 per 10,000 of unrelated persons the expectation is increased 7-fold for offspring of single first cousins and 26-fold for offspring of parent-child incest.

Since this effect will be observed by the clinician the other way round, by merely inquiring about consanguinity in the parents of single patients he may acquire some valuable information on the mode of inheritance. If the disease is caused by recessive factors, the proportion of cases in which subjects report consanguinity will be considerably larger than the proportion of such matings in the general population. Rare dominants, on the other hand, will not be caused to appear in greater frequency through inbreeding.

Penrose[8] has recently suggested that it might be equally advisable for the medical worker to inquire about consanguineous marriage in the grandparents. Certain anomalies of development suggest that they may be conditioned by the genotype of the mother rather than that of the child. Hence, if the genetic factor were a recessive, the defect would be associated with excess consanguinity in the maternal grandparents. Abnormalities due to certain kinds of chromosome derangement might also be expected to show this effect.

Most of the known pathological genes of man are of the sorts known as dominants, "provisional" dominants and "irregular" dominants. Only a single gene is necessary to produce the defect in some, if not all, individuals. Whether the gene is incompletely dominant, that is, whether it would produce a more severe defect in double dose, is usually unknown since, being rare, the gene is never given the opportunity of occurring in that state. Now since only a single gene is required, we see that the probability of any relative being affected is simply equal to the coefficient of relationship, for $A_1 + A_{12} = B_1 + B_{12} = r$. So if we examine the relatives we expect to find the defect appearing in one half of the parents, children and sibs; in one fourth of the grandparents, grandchildren, aunts, nephews, etc.; in one eighth of the first cousins; and so on.

[7] Sewall Wright, *op. cit.*

[8] L. S. Penrose, *Trans. Roy. Soc. Canada*, Sect. V, p. 93. 1940.

This is only true, however, if the gene is rather rare, if segregation is normal and if the gene always expresses itself when present. The last of these conditions is frequently contradicted in human inheritance; the gene is then irregular in its expression, producing the abnormality in only a certain fraction of the individuals in which it occurs. The study of the causes of this variation in expression is clearly one of considerable practical importance in medicine. In any case, we see that unilineal and bilineal relatives of the same degree are of equal value in the study of dominant genes.

When an instance of probable dominant inheritance is found, it is naturally advisable to attempt to trace the transmission of the gene through as many groups of relatives as possible. The distant relatives here become of interest not because they contribute additional information about the genetic constitution of the original patient but merely because they will very probably provide some additional affected individuals for study. The elaboration of extensive family histories is therefore not essential to detailed genetic study, but it provides an economical procedure for securing large quantities of material in the case of rare dominant conditions.

In seeking an answer to the question, Is such-and-such a condition hereditary?, it would perhaps seem most pertinent to ask: Was the condition inherited in the case of the patient? Attention is therefore immediately directed to the parents. Now of course an affirmative answer need not require that one or the other parent be affected. A "negative family history," at least with respect to the parents, is almost always expected in the case of recessive inheritance. It will also frequently be found in the case of irregular dominants. But even for regularly expressed dominant genes there is an additional reason for occasional or even frequent absence of an affected parent. Every abnormal gene must have some starting point and such spontaneous changes from the normal gene are termed *mutations*. Tracing back any dominant gene through successive ancestral generations, we are frequently able to discover such starting points and, indeed, would always expect to find them if the pedigree could be extended indefinitely. On statistical grounds which need not be presented here, it can further be stated that the rarer the abnormality the more commonly will such "sporadic" cases appear, and especially so if the defect is associated with a lowered fertility. For example, Haldane[9] estimates that about one in every three hemophiliacs has not inherited in the ordinary sense but represents an original mutation.

The realization of this fact is of practical importance for two reasons. First, a failure on the part of the clinician to report such cases will rob the geneticist of the opportunity of measuring one of the most fundamental of all genetic phenomena, *viz.*, mutation. Secondly, in so far as mutation is actually responsible for the exceptional cases, the defective patients must be regarded as the potential starting members of new family lines carrying the abnormal gene. Owing to mutation, then, it appears that the question, *Will* the condition be inherited?, is somewhat more significant than the question: *Was* it inherited?

So far we have somewhat slighted the importance of parents. Returning to our general formulae of genetic resemblance, we note that with $r=\frac{1}{2}$ we have the unique condition, $A_0=0$, and for this reason we may regard parent-offspring relationship as a special subclass of A-relationship. Parent and offspring *must* share one or the other of their genes: $A_1=A_2=\frac{1}{2}$. This commonplace is responsible for several genetical advantages in the comparison of parent and child. In the study of relatively common hereditary variations, pairs of parent

[9] J. B. S. Haldane, *Jour. Genet.*, 31: 317, 1935.

and child will be generally somewhat more useful than pairs of brother and sister, and when both parents are included the information is usually increased very greatly. Also, the measurement of dominance or non-additive gene effects in the case of quantitative inheritance depends largely upon the comparison of parent and child.

Obviously the consideration of individuals as parents is essential to the investigation of the evolutionary factors of mutation, selection and population mating systems. In this last respect, man, because of the institution of marriage, possibly enjoys a distinct advantage over other species as an object for genetic study.

Unselected Data

There are two somewhat different methods for securing human genetical data. In the one procedure the investigator obtains an unselected sample of families or other groups of kin—unselected at least with respect to the characters in which he is interested. Obviously such a method will be found suited to the investigation of only such traits as are not too unequally distributed in the population or are of such a nature that selective sampling can not be conveniently employed. The ABO and MN blood groups, as well as taste reaction to phenyl-thiourea, are examples of traits which possess both of these features. For example, "tasters" and "non-tasters" occur in our population in about the ratio 7 : 3. This means that from one third to one half of all families taken at random (depending on their size) will show variation amongst the children and will therefore be of use in testing genetic ratios. However, even were such circumstances far less favorable, a random collection of data would still be in order by virtue of the fact that taste ability is a characteristic which does not make itself known to the subject or the investigator until a special test is performed.

Inherited characters suitable to random investigation are therefore likely to be of the sort described as "normal" traits. Table I, which is reproduced from Wiener,[10] summarizes a typical body of such data. One hundred families tested for the ability to secrete A, B or 0 agglutinogens in the saliva are classified here according to the three possible parent combinations. **S** denotes a secretor, and **s** a non-secretor.

TABLE I
Heredity of the "Secretor" Factor

Parents	Number of families	Children	
		S	s
S × S	51	134	21
S × s	38	64	44
s × s	11	0	28
Totals	100	198	93

The fact that non-secretor "breeds true" suggests the hypothesis of simple recessive inheritance of this property. To test the hypothesis we must then examine the ratios of S and s children in the two other matings, S × S and S × s. This might be done by first selecting from these matings all families with some s children. The analysis would then be similar to that described in the following section. If, however, it is desired to apply a test to the whole of the data, we must employ an analysis based on the computation of gene frequencies. It will be observed that the numbers of S and s children in the first two matings do not suggest any simple Mendelian ratios, such as 3 : 1 or 1 : 1. These, in fact, are not to be expected, for, on the hypothesis adopted, these matings must contain mixtures of different genotypes. This is an invariable feature of such data and it requires that we estimate the composition of such mixtures in terms of the gene frequencies. A wide variety of such

[10] A. S. Wiener, "Blood Groups and Blood Transfusion," 2nd Edition. Springfield, Ill.: Chas. C Thomas, 1939, p. 191.

gene-frequency methods is now available for many kinds of inheritance and many kinds of data. The more important of these have been summarized by Professor Snyder.[11]

In addition to their use in genetic analysis, gene frequencies are of considerable interest in themselves, as Dr. Strandskov has shown in a previous article in this series. It is therefore one of the advantages of randomly collected data that it facilitates the estimation of such gene frequencies. Fisher, however, has recently called attention to a complication in the determination of gene ratios which has not been considered by other authors. I should like to mention this point here since it involves the general topic of relationship.

Suppose we wish to estimate the frequency of the recessive non-secretor factor from the data of Table I. Since this is taken as the square root of the proportion of non-secretors, the problem is equivalent to estimating this latter proportion. Now if we consider the parents alone, the proportion is simply 60/200, while for the children we have 93/291. These two estimates are indeed very similar and ordinarily they would be combined to give 153/491. However, it would be incorrect to ascribe to this estimate, as is commonly done, a standard error equivalent to one based on 491 independent observations. An observation of two relatives will, in general, not carry the same precision as one based on two unrelated persons, but should have a weight varying between 1 and 2. This is easily understood in the extreme case where the coefficient of relationship $r=1$; 100 pairs of one-egg twins (200 individuals) are clearly equivalent to only 100 single unrelated individuals. The general procedure for estimating gene frequencies in data containing relatives has been outlined by Professor Fisher.[12]

Selected Data

In the study of rare conditions the standard procedure is to examine only the relatives of affected persons who are encountered in a clinic, hospital, school or similar institution. After amassing data of this sort, the geneticist will then examine the frequencies of affected individuals amongst the various classes of relatives. Such a method of gathering data is obviously selective and might be expected to introduce some troublesome problems in connection with the statistical treatment. This is true, but it is interesting to note that the chief difficulty is one which arises only in connection with the sibs. That is to say, ordinarily the selection will not disturb the proportions affected amongst the parents, children, cousins, etc., but only amongst the sibs. This circumstance is traceable not to any genetic peculiarity of sibs but merely to the fact that the patient *himself* is to be included in the sibship.

The reasons for the disturbance of the sib proportions are explained very concisely by Professor Haldane,[13] in the following manner: "If I asked every child leaving school in London this year how many brothers or sisters he or she had, and then calculated the average, it would be much higher than the average family size of London. First of all, I should have no representatives of childless families. Secondly, I should have ten times as big a chance of getting a child from a family of ten as from a family of one. So I should greatly exaggerate the number of large families."

In estimating the proportion of affected individuals in sibships we have a very similar problem. First, we omit cases where the parents could have produced a defective child but, by chance, failed to do so. This is easily corrected and need not worry the person who col-

[11] L. H. Snyder, *Eugenical News*, xix: 61–69, 1934.

[12] R. A. Fisher, *Ann. Eugen.*, 10: 160, 1940.

[13] J. B. S. Haldane, "Science and Everyday Life," New York: Macmillan, 1940, p. 268.

lects the data. The second difficulty, however, is more serious. Let us imagine two sibships of 5 members each, one containing three persons with, say, harelip, and the other only one. Now the sibship of three affected members may or may not have a greater chance of being found than the sibship with the single member. If the search for families showing this defect were exhaustive, so that every harelip in the area sampled would be certain to be found, then both of our sibships of 5 would of course get on record. If, however, only a portion of the available harelips were encountered, the sibship of three defectives would have a greater chance of being recorded, since it might be brought to light through any one of the three individuals.

To rectify this difficulty we must, in effect, estimate what fraction of the available cases was studied. This would indeed be of considerable interest, for, in addition to disentangling our present problem, it might also lead to an estimate of the incidence of the disease in the general population. Fortunately, it can be done if the clinician takes care to record which of the affected persons were the original patients or *próposití*. More exactly, he should specify, for each affected individual, whether that individual was a primary or a secondary case, that is, whether the person was encountered individually in the clinic or school or whether he was only brought to light through an affected relative. Often a kindred involving several affected members will contain a single propositus, but occasionally two or more will have been patients in the clinic or inmates of an institution.

The problem is clearly a very important one since, as we have seen, the sibs will always contain a large store of genetic information. Unfortunately, the marking of propositi is frequently omitted in the publication of family histories and much genetical value is therefore lost. In some kinds of studies it is possible that the classification, primary and secondary, will seem inappropriate; there might be more than two conditions of ascertainment or the unit might be a group rather than an individual. In such cases the investigator can do no better than to state exactly what these conditions were and trust that an appropriate statistical treatment can be devised.

Summary

In conclusion, it would seem safe to say that any observations, to the extent that they are of value individually, will also be of value to the human geneticist, if only they contain relatives. Amongst relatives of the same degree, some kinds will be much more useful than others in the investigation of particular genetic phenomena. When the data are sought for unknown purposes or for several kinds of analysis, we can profitably adopt the rule that closest relatives are of greatest value. Even two relatives—parent-child, sibs, or twins—will often supply considerable information, though entire families are generally much preferred. Most important is the careful recording of the circumstances under which each person was obtained for study.

PERSPECTIVE OF PUBLIC HEALTH IN THE UNITED STATES

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The possession of perspectives is perhaps the most significant symptom of intelligent and scientific competency. The great difficulty of the present time on the part of the masses and even the intellectuals and statesmen in economics and politics consists in obtaining sufficient facts and developing the organizing technique for realizing their full luminosity. Due to the fact that our health field has become so expanded and intricate and that our health efforts are highly individualistic and uncoordinated, our health perspective is liable to be blurred.

In seeking to establish a historical perspective of public health, pronounced limitations appear. Some things are clear and others are vague. Much of the story of mankind in matters of health are almost closed chapters. Except from observation of contemporary primitive peoples, we know next to nothing about man's hygienic and health status during the many hundreds of thousands of years of his preliterate days. But it is certain that the death rate just about equaled the birth rate during that period because the world's population remained small and dispersed. The fact that it required something like a million years for the world population to number about 900,000,000, while about one and a quarter billion inhabitants have been added during the century and a third since that time shows that during the most of man's earthly career he was scarcely able to survive the bitter struggle for existence. Foods were rough, famines were frequent, pestilence often ravaged populations, animal and human enemies took their heavy toll and births were relatively infrequent because of long nursing periods which in turn were the outcome of crass foods unsuited to the young.

Recorded mortality rates do not reach far back into history, and we know nothing of morbidity rates until very recently. The latter would be a better criterion of the state of health of a people than the former because morbidities are so much more frequent than mortalities. Most persons get ill or incapacitated many times during their lifetime but die only once. The federal health survey of 1935 found that in this country on any winter day there are six million persons who are incapacitated from duties by illness or accident.

Since incapacities from daily morbidities from accidents are only a fraction of one per cent., all incapacitations may be thought of as arising from morbidity. Summer morbidities are much fewer than those of winter. Consequently, let us assume an average of 3,000,000 incapacitations a day throughout the year. This would give an annual rate of incapacitations from morbidities of 8,690. From these data and from the estimated number of deaths for any given day of the three heavy winter months, the calculation is made that on such a day there are 1,336 incapacities from morbidity for each death. But since we do not have published federal records of morbidities for our nation and states, we are compelled to study general health conditions by means of mortality data.

Records of European death rates begin early in the nineteenth century with two countries and increase in number of countries until there are eight in 1860 and 20 in 1930. The approximate aver-

age death rate for the three countries reporting for the five-year period 1808–1812 was 29.5, and the death-rate range was from 23.1 to 39.8. The eight countries reporting for the period, 1848–52, had an approximate mean rate of 22.6 and the approximate mean rate of the 20 countries reporting for the period 1928 to 1932 was 14.3 and their death rates ranged from 9.6 to 20.7. The decline of mean rates from 29.5 to 14.3 was quite regular, indicating an orderly and regular improvement in public health.

One might have expected a great drop in the curve after the germ theory of disease came to be adopted as basic to medicine and public health about the close of the last century. No such revolutionary incidence in medicine affected the mortality rate in an apparent manner. Probably the most important contributor to this result was the improvement in the amount of subsistence during that century which was made possible by the agricultural revolution and the industrial revolution. The masses had their food and other living standards increased and improved as never before. We are just now recognizing that improved nutriment is the greatest foe of disease and death. Of course medicine and sanitation by reason of antiseptics and improved engineering devices affecting water supplies and disposal of sewage also made their contributions. Life has been made safer in great cities, and in the United States the death rate in some of them is lower than that of rural populations of the same area.

There are "scientific guesses" that prior to the eighteenth century or thereabout, the mortality rates of these European nations must have been very much higher than those at the beginning of the nineteenth century. They were so high that they compelled a very slow population growth, which means that they about equaled the birth rates, which must have been very liberal. It is reckoned that in such great cities as London the death rates were above the birth rates and that the cities grew only from attracting country people whose surplusage of inhabitants were the outcome of high birth rates and lower death rates.

The health picture of that age in general was probably similar to that of sample rural areas of China to-day. A recent survey of the Ting Hsien area, consisting of forty-four square miles and a population of 44,190, or an average of about 1,000 per square miles, reveals the following things. The inhabitants live in sixty-one villages, ranging from 100 to 2,600 per village. The average size of family farms is five acres and the average annual income is six to seven dollars (gold). The fifty-eight primary schools enroll 2,540 children at the general per capita cost of two dollars. Half of the sixty-one villages have a modicum and the rest have no medical facilities. Trachoma and ringworm, dysentery, summer diarrhea and typhoid fever are prevalent. Tetanus, neonatorum, smallpox and scarlet fever are the chief causes of death. There are no scientific checks on epidemics. The general birth rate is about thirty-two, and the general death rate about thirty-one. Thus the population is practically stationary.[1]

Recorded death rates in the United States began in 1880 with the first registration area, consisting of two states, Massachusetts and New Jersey, and the District of Columbia, comprising about 17 per cent. of the population of the nation. What mortality rates were obtained previously can only be estimated roughly. An approximate idea of what they were during the first three decades between 1790 and 1920 may be obtained from the decennial population increase and the amount of immigration. The former was about 35 per cent. a decade, a rate of 35 per thousand a year. The immigration amounted to an average of 91,600 a decade, or about 5 per cent. of

[1] C. C. Ch'en, M.D., M.P.H., *Milbank Mem. F. Quar. Bul.*, 11: 95–129, April, 1933.

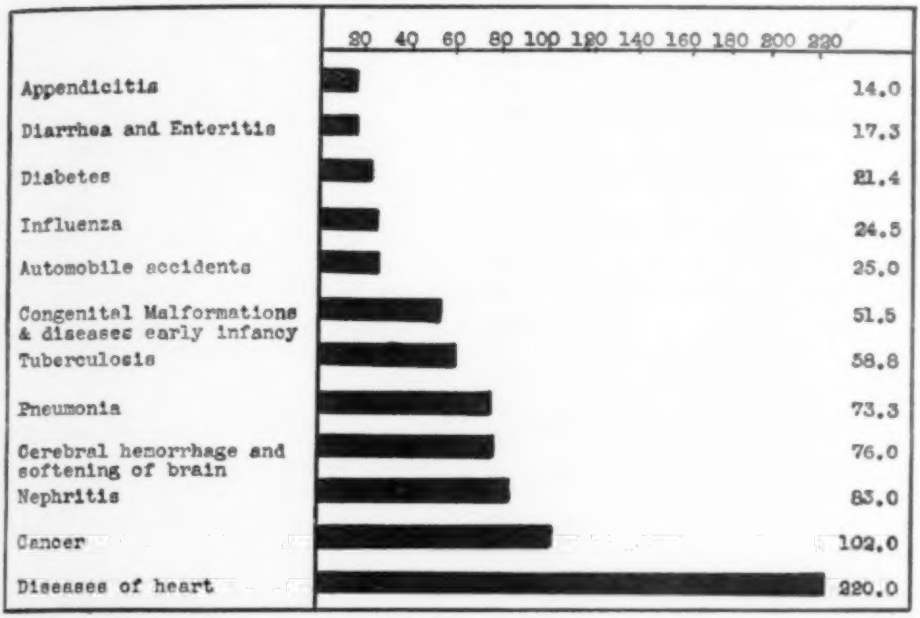

FIG. 1. MEAN DEATH RATE PER 100,000 FOR SPECIFIED CAUSES OF DEATH IN THE UNITED STATES FOR THE PERIOD, 1932–34. MEAN NUMBER DEATHS, U. S., 1932–34: 1,346,099. DEATHS FROM HIGH SIX IN CHART FOR SAME PERIOD 779,804—58.8 PER CENT., OF ALL. DATA FOR ESTIMATES FROM MORTALITY STATISTICS, 1932, AND FROM ADVANCED "RELEASE SHEETS" OF CENSUS BUREAU, 1936.

the amount of population gain. The difference between immigration and population increase represents the natural increase, the excess of births over deaths. This yields a rate of about thirty-three. To realize such a rate of natural increase demanded a very high birth rate. Were that rate fifty, the accompanying death rate would have been seventeen. Probably the latter was close to the real death rate then, for the farm population would probably average about 80 to 85 per cent. of all for the thirty years. This farming population had an abundance of land, food, fair housing, plenty of fuel and ample clothing. It was a well-kept population in terms of subsistence and should have sustained a relatively low death rate. Epidemics would constitute the great causes of death. The death rates would be much lower than those of European countries of that time because of the abundance of subsistence here.

Our crude death rate in 1880 was 19.8 per 1,000 of the population. In 1890, when the registration area included over 31 per cent. of the inhabitants and eight states besides the District of Columbia, the death rate was almost that of 1880, 19.6 per 1,000. The curve of the mortality rate fell very rapidly till 1900, and then still more rapidly and quite regularly on the average until by 1935 it was 11.0 for the 1880 registration area and 10.8 for the whole national area. Judging by the fact that the original registration area had a rate in 1935 which was almost exactly that of the whole national area, we might conclude that the rate of 1880 was representative of the whole nation. The only marked variation from the downward trend of the national mortality rate occurred in 1918 when the death rate mounted to about 18 from a level of about 13.5 in 1915. The large fluctuation was of course due to the "flu" epidemic of that period.

Are we to attribute the rapid fall of

death rates after 1890 to the placement of medical practice on the basis of the germ conception of contagious disease or to the inclusion in the registration area large sections of the best-conditioned farming states with their more ample subsistence levels? Certainly reduction of deaths from contagious diseases has greatly affected the general mortality rate. But we do not dare impute too much to that, since the fall in European death rates prior to the discoveries of Lister and Pasteur were about as marked and gradual as those subsequent to them.

This downward trend in mortality rates has been favorable to every age class of our population, although the gains to those under ten years of age are greater than those of any other age class. Between 1900 and 1932 even the aged, the population class of 75 and over, have improved their health status, as is indicated by their more favorable death rate. It is most satisfying to note that only a third as many infants proportionally die to-day as in 1900 and that the gains to those under five is even greater.

Are we to expect a continuation of the downward trend of the mortality rate in future of the same nature as that obtaining since 1900 or may it follow the horizontal henceforth or even make an ascent? The answer to this question is to be found chiefly in the changing age composition and in the changed nature of the chief causes of death which confronts medical care. The latter item will receive attention later in this article. Regarding the former, the import of age composition is seen in the statement that for a population with average length of life of sixty years and which, at the same time, is stationary (not increasing by excess of births over deaths or by immigration), the death rate must necessarily be about 16.7. Should our national population become stationary (predicted for the near future) and did we maintain our present average length of life (about sixty-three), then our death rate will be forced up from the present ten or eleven to nearly sixteen. That might occur, however, without any deterioration in public health conditions.

A very considerable portion of health gains during this century have come from improved control of germ diseases. In 1935, contagious diseases accounted for 9 per cent. of all deaths, in 1912 for about 21 per cent. Some diseases, such as smallpox and diphtheria, have almost disappeared and tuberculosis has been robbed of its place as the leading mankiller.

The accompanying figure, Fig. 1, gives the picture of our twelve chief mankillers for a period of years, 1932–1934. The mean for the three years is used in order to obviate annual fluctuations.

These twelve causes represent 72.5 per cent. of all deaths during that period and therefore show where the chief health problem lies, so far as causes of death can denote it. The "big six," lower half of chart, account for 58.8 per cent., or nearly six out of every ten deaths. Diseases of the heart levy a death rate nearly sixteen times that of the lowest, appendicitis, over twice that of cancer, and nearly four times that of tuberculosis, formerly the chief cause of death. In 1935, diseases of heart, excluding coronary troubles, occasioned 19.5 per cent. of all deaths of that year. In this formidable list, only two contagious diseases appear, representing only 8 per cent. of all deaths. Deaths by auto accidents, very important, are a little over one a hundred of all deaths, and fortunately they have become proportionally less during the last two years.

The big fight in the field of health and medical care of the future, then, so far as mortality rates are an indication, is not to be against contagious diseases but against the nine non-contagious causes of the chart. Some of these greatest among man-killers are, as yet, under slight control. Various forms of heart

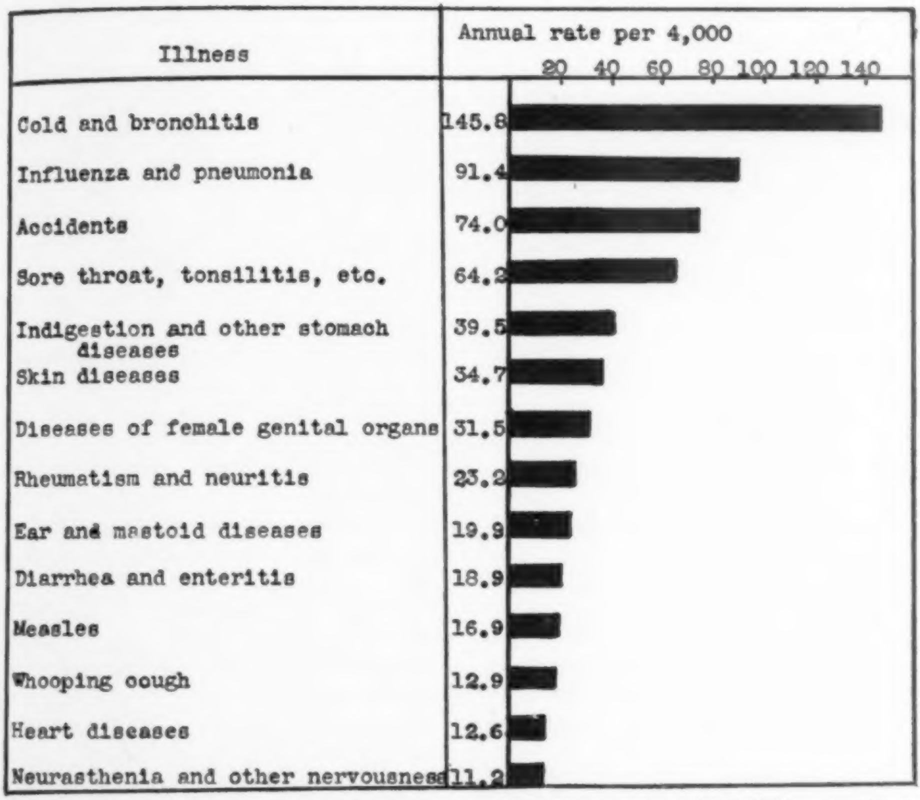

FIG. 2. INCIDENCE OF ILLNESS BASED ON NATION-WIDE PERIODIC SURVEYS, 1928–1931. REPRODUCTION OF FIGURE IN "THE NEXT STEPS IN PUBLIC HEALTH," MILBANK MEMORIAL FUND, BY EDGAR SYDENSTRICKER, N. Y., PAGE 31.

disease are not curable but only mitigable. And what is true of heart troubles is true of cancer generally. A large proportion of the most troublesome diseases are terminal in nature, develop with age and represent the accumulated scars contracted during the battle of life. We share in the scientific hope and expectation that ultimately all of them, one by one, will succumb to the discoveries of scientific workers and come wholly or in large part within control. What sulfanilamide and its derivatives are accomplishing in the field of pneumonia and elsewhere is a harbinger of what may be discovered and practiced for any of the others.

A comparison of a morbidity chart, Fig. 2, with the one just noticed reveals quite a different set of causal factors as afflictions and incapacitators of mankind. In it germ and contagious diseases are observed to be the "big chiefs" of morbidity. Diseases of the heart have less than one eighth the force of colds and bronchitis, while cancer does not appear on the list.

The causal factors in morbidity may be given as follows: Germ and contagious diseases may be considered to be the "big chiefs" of morbidity. Diseases of the heart have less than one eighth the force of colds and bronchitis, while cancer does not appear to be a causal factor. These are the ailments and external incidents which incapacitate people for work and

duties. These are the predominant causes which incapacitate an average of 6,000,000 persons any winter day, according to the national public health survey of 1935–36. They also serve as the fostering foundation of many of the terminal diseases which trouble people in middle or later life. According to these morbidity data, and from the point of view of morbidity alone, the big health problem is one of controlling these ailments which incapacitate millions daily for duty, sap their vitality, cripple their economic efficiency and lay the basis for the inroads of more serious diseases later in life. It is a matter for debate which is the chief field for society to attack, the ailments presented in the mortality or morbidity charts. Viewed in relation to immediate life termination, mortality causes hold first place. But thought of quantitatively, in case number, and as incapacitating for functioning in life processes, morbidities are far in the lead, since, as was said, on any average winter day there are 1,336 incapacitating illnesses for every mortality.

Something that should be of profoundest significance to health workers is the distribution of death rates and the causes of such distribution among the states. Unfortunately, neither the general public nor the trained health fraternity has a really scientific and objectively determined comprehension of either, and especially the latter. With a very few exceptions, it is a guess regarding whether a regional change or if this or that region will act beneficially upon patients who have specific ailments. What we should know we do not know for two reasons: First, the facts relative to distribution have not been published in such form as to make them visual; second, the causes of mortality distribution in general and specifically have not been determined. This study has ventured into this field. It supplies available information concerning the distribution of several classes of mortality rates throughout the nation by states, and it investigates observationally and statistically the field of causation accounting for the spread.

In order to iron out annual fluctuations, estimates have been made of mean crude death rates for general and specific causes of death for all the states for the three-year period, 1932–34. The specific rates are those of the six greatest mankillers. And so that the distribution patterns may be observed at a glance, they are embodied in cartographic maps, one for general mortality and the others for each of five specific causes. All maps are built on the same principle. The highest rates are represented by darkest shadings and the lowest by the lightest shadings, the others graduating between the extremes. For the benefit of the observer of the charts it seemed advisable to tabulate the class limits of the death rates of the maps in Table 1, since reduction in size for publication purposes has obscured them.

The range of variation in the general rate is from 7.9 in North Dakota to 13.7 in Nevada, per 1,000. The variations in specific rates (per 100,000) are as follows: In diseases of heart, from 102.1 in Arkansas to 381 in the District of Columbia; in cancer, from 44.5 in Arkansas to 157.5 in New Hampshire; in nephritis, from 44.8 in South Dakota to 141.9 in Delaware; in cerebral hemorrhage, etc., from 36.8 in Louisiana to 136.1 in New Hampshire; in tuberculosis, from 20.2 in Nebraska to 239 in Arizona; and in pneumonia, from 48.5 in Oregon to 119.6 in the District of Columbia.

A critical inspection of the general death-rate map (Fig. 3) makes some things apparent. We are struck by the absence of a dominant regional pattern. Most any class of mortality rates may occur most anywhere. The nearest to a dominant regional block lies in the northern Plains and Rocky Mountain region, a low rate area. But low rates also appear in the southeastern states.

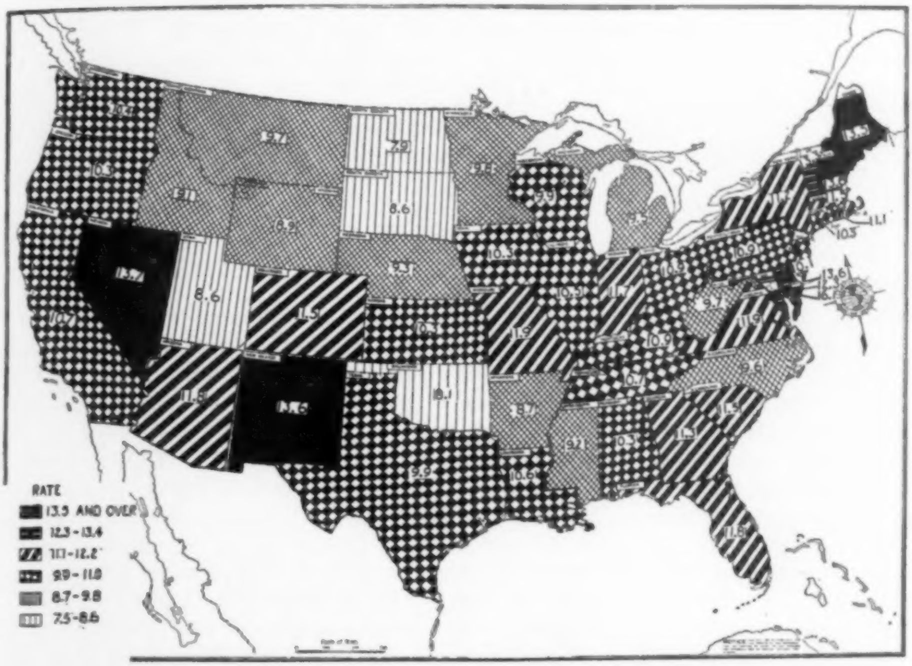

FIG. 3. MEAN DEATH RATE, UNITED STATES, 1932–34, BY STATES.

When the cause of this distribution pattern is sought, we become aware of two things: First, the presence of a *number* of determining factors, of which there are several classes—geographical, such as precipitation and temperature; biological, as seen in age composition; and cultural, evinced in migration of population between regions, per cent. of population that is urban, degree of schooling and per capita income. No one set or kind of condition accounts for all differences in distribution. Second, the determination of the exact weight exercised by any set of causal conditions can not be scientifically reckoned. This is typical of attempts to discover the exact division of labor among social forces which produce situations and problems. However, by means of this research effort we have learned something about causes of mortality distribution of both a negative and positive nature. It is possible to say that some factors are not important and that others are significant as causes.

A geographic determinist would not extract much satisfaction from a critical inspection of this spot-map. The medical man who wrote a book to demonstrate that differential death rates of North and South are due to differing climatic conditions evidently never confronted such an array of distributive mortality spot-maps as the series of this study reveal. If Ellsworth Huntington's "zone of energy" were based on death rates, it would be very partial. An attempt to explain the variation in rates solely by differences in physical environment immediately confronts confounding contradictions. Two sets of facts at once become obvious. First, states having identical climates, such as Nevada and Utah or Texas and Oklahoma, exhibit great extremes in death rates; second, identical mortality rates in states having most diverse geographical conditions, as seen in the case of North Dakota and Oklahoma or in that of Maine and New Mexico.

North Dakota is cold, dry, has long

TABLE 1

CLASS LIMITS OF SPECIFIED MEAN DEATH RATES, 1932–34

General per 1,000	Specific per 100,000					
	Heart	Cancer	Nephritis	Cerebral Hem., etc.	Tuberculosis	Pneumonia
13.5 and over ..	340–383		125–144	118–139	106–239	48– 57.8
12.3–13.4	280–339	136–167	105–124	96–117	82–105	60– 74.9
11.1–12.2	220–279	104–135	85–104	74– 95	58– 81	76– 89.9
9.9–11.0	160–219	72–103	65– 84	52– 73	34– 57	90–104.9
8.7– 9.8	100–159	40– 71	45– 64	30– 51	20– 33	105–119.0
7.5– 8.6						

winters and a low precipitation rate of generally less than twenty, while Oklahoma is hot, generally has a rainfall much greater than North Dakota, has long summers and mild winters. The only common climatic element is low precipitation in the western portions of the states. On the other hand, take Montana and Mississippi, states having similar death rates, for comparison. Montana has a high altitude, is low in precipitation, has long cold winters, while Mississippi is the reverse in all particulars. New Mexico, with a dry climate, high elevation, almost no winter except in the mountain areas, is to be compared with Maine, which is the opposite in all these respects. In the same manner we observe other pairs of states, such as Maine and Nevada, Wisconsin and Texas, etc.

The similar high rates of Maine and New Mexico are to be explained probably in large measure with respect to age composition and migration, the latter being in turn a large cause of the former. In New Mexico, 43 per cent. of the population in 1930 was between the ages of five and twenty-five, the period of lowest death rates, while in Maine but 35.5 per cent. of the inhabitants were so aged. In contrast, the percentages of persons who were sixty years old or more, the age period of greatest death rates, were 7.4 in New Mexico and 12.8 in Maine. This alone would place Maine high in the death-rate list. Both states have been influenced by migration. Maine has lost younger people to the West formerly and to eastern cities more recently, while New Mexico has received young inhabitants. This helps explain why the Maine population is older than that of New Mexico. Into New Mexico also have migrated many tuberculous and perhaps other ailing individuals, many of whom have died there and swollen the death rate. This goes far to explain the high mortality rate there. The geographical factor in the case of New Mexico appears as an indirect cause of the high death rate. Its favorable climate has attracted the diseased individuals who have died there, but the climate did not kill them.

One is apt to think that the explanation of the distribution of specific death rates would be comparatively simple, as the case of death from hookworm. But such is not the case, as a review of the situation in some detail suffices to show.

Fig. 4 shows how mortality rates from diseases of heart are reported by the federal census. Variations are pronounced, but there seem to be regional patterns. The areas of highest and high rates are northeastern and extreme western United States, the Plains, eastern Rockies and South generally showing lowest and low. A physician might very well advise his heart patients, if a change were thought desirable, to go to the South or to the extreme central North.

The tendency among those who see these charts is to explain mortality distribution in terms of climatic conditions. Causatively, climate does not appear to amount to much as an explanation of this distribution. Regarding temperature, low death rates obtain in numerous

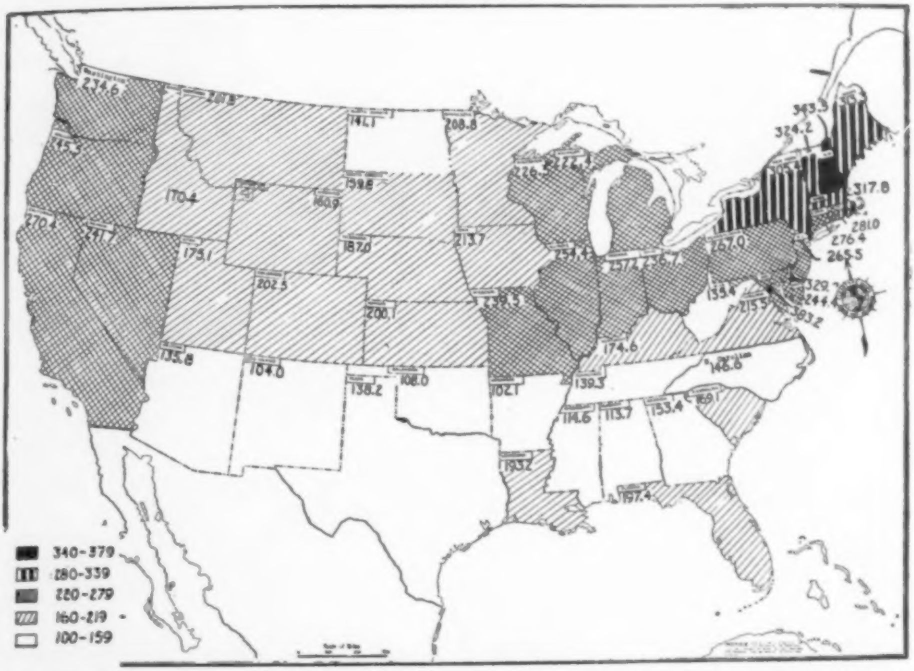

FIG. 4. MEAN NUMBER OF DEATHS PER 100,000 FROM DISEASES OF HEART, UNITED STATES, 1932–34.

cases in hot and cold regions, and the same is true regarding precipitation or moisture. One can not claim too much for cold or dry as being conducive to avoidance of heart troubles. This conclusion is substantiated by applying the method of correlation to two sets of variables, that of heart death rates among the forty-eight states and District of Columbia as one series with each of two others, mean temperature and mean precipitation. The former gives a coefficient of -0.27, with a probable error of .09 and the latter one of -0.04, with a probable error of .10. Since in both cases the probable error is more than a fourth of the coefficient, the latter has little or no significance. It is understood that correlation is useful, when intelligently applied, as a clue to causal relationship obtaining between series of variables.

Cultural environmental factors do appear as influential in explaining the distribution pattern. Both per cent. of population that is urban among states and the per capita income among states, when correlated with the heart mortality series yield highly significant coefficients. The coefficient of urbanism with heart death rate is 0.75, with a probable error of .04. That of heart death rate with per capita income is 0.73, with a probable error of .05. These mean that the greater urbanism and per capita income are, the higher is the death rate from heart disease. Thus both coefficients are significant. But the coefficient between urbanism and per capita income is 0.79, indicating that they are closely associated. To discover what is what, an application of partial correlation, when per cent. urban is held constant, yields a coefficient of 0.34, with a probable error of .085. Thus it is shown that it is not the per capita income but the degree of urbanism that is the important causative factor. We conclude that heart mortality rates graduate upward with per cent. of population which is urban.

The distribution of the death rate

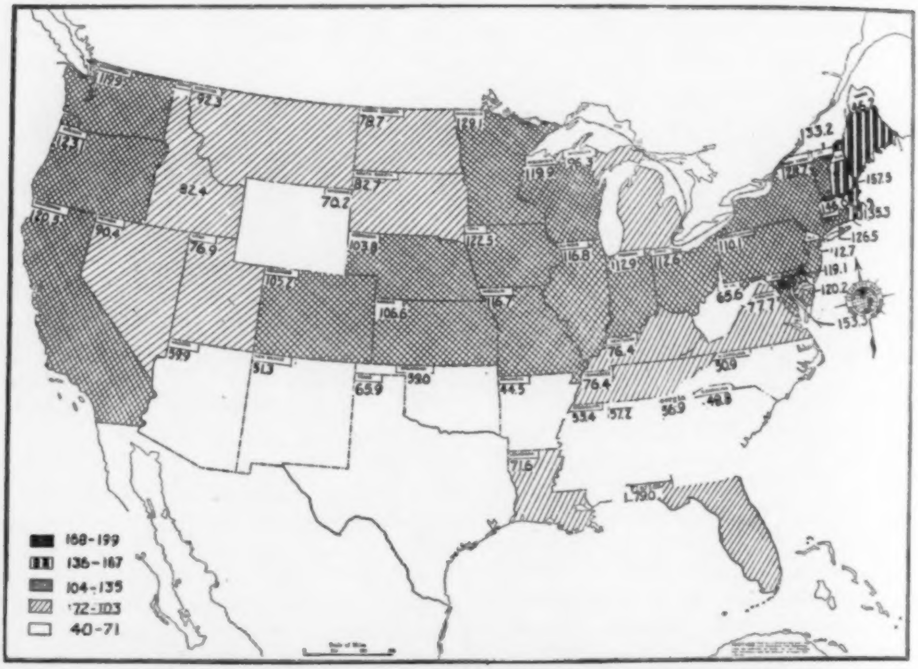

FIG. 5. MEAN NUMBER OF DEATHS PER 100,000 FROM CANCER, UNITED STATES, 1932–34.

from cancer may be visualized by inspecting Fig. 5. Regional patterns are at once apparent. Lowest class areas are found in the southeast, southwest, eastern Rockies and northern Plains. The District of Columbia represents the highest class rate and New England next highest. Although they at first appear large, geographical influences are not at all influential. Again there are many cases of similar rates in states of widely differing climatic conditions and different rates in similarly located states. The District of Columbia stands out in glaring contrast with the southern states generally, and West Virginia contradicts Ohio or Pennsylvania, but there is considerable causality between temperature and the cancer death rate, since the coefficient of correlation is not much impaired after applying partial correlation, holding degree of urbanism in control. This results in a coefficient of −0.52, with a probable error of .07. Thus the interpretation reads: The higher the temperature, the lower is the cancer death rate, on the average. A physician would be justified in advising cancer patients to go South or to west central United States for favorable climates.

Living under urban conditions appears as a decisive factor in the distribution of the cancer death rate among states, the coefficient of correlation between the death rate series and the urban series being 0.67. This of course reads that the death rate increases with the per cent. of inhabitants who live in cities. The coefficient of correlation between cancer series and that of per capita income is 0.70 with a probable error of .05. This looks significant, but when partial correlation is applied between cancer death rate, per capita income and per cent. of population that is urban, holding the latter in check, the insignificant coefficient of 0.28 with

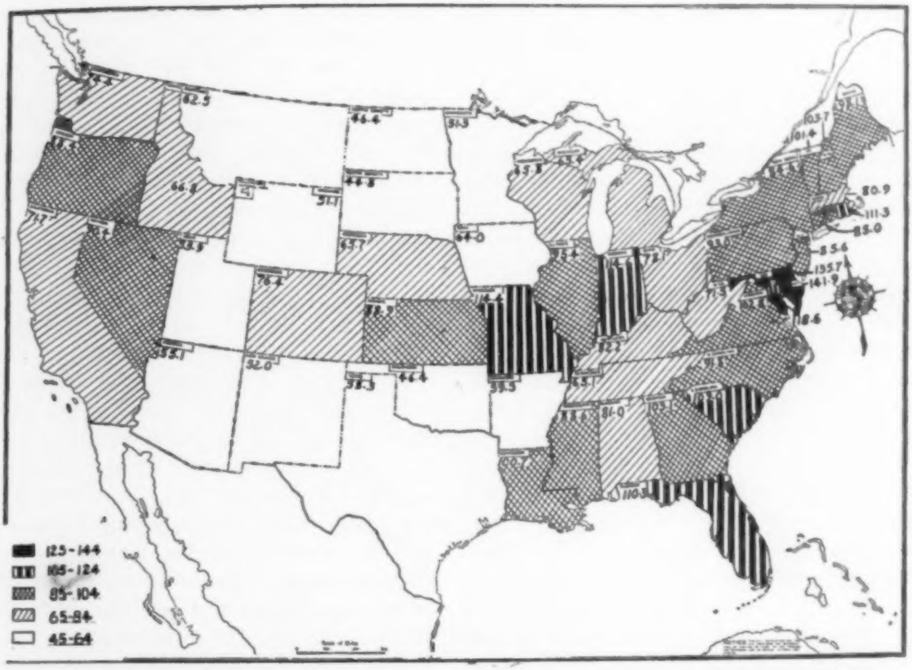

FIG. 6. MEAN NUMBER OF DEATHS PER 100,000 FROM NEPHRITIS, UNITED STATES, 1932–34.

probable error of .085 is obtained. We conclude that per cent. urban rather than income is the great cultural causative influence. What element in urbanism it is that is influential is yet open to guess. It may be that diagnosis improves with degree of urbanism. In reality the death rate in rural and urban populations might be the same, but better diagnosis in cities brings more of it to light.

After consulting Fig. 6, showing the distribution of the mortality rate from nephritis throughout the states, a physician would be inclined to advise patients to avoid the area east of the Mississippi generally and the Pacific coast region and to settle most anywhere within the Great Plains and eastern Rocky Mountain areas, with the exception of Louisiana, Missouri, Kansas and Nevada. But if he justified his advice on grounds of climate, he would overlook some very contradictory facts. The cold and dry northern plains and mountain states have the same low death rates from nephritis as do the hot moist states of Arkansas and Alabama, while hot states like Arizona and Florida have most divergent rates. If he were wise and honest he would say he does not know why, but supposes there are influential social environment factors which also intervene. Or if he were statistically inclined he might try out some correlations. Then he would find a somewhat significant coefficient between nephritis death rate and temperature of 0.44, with probable error of .09, and a more significant one between death rate and precipitation of -0.67, with a probable error of .07. His explanation would then be that to a small extent nephritis mortality increases with temperature, but to a considerably greater degree it decreases with the amount of precipitation. The ultimate whyness of that he would have to tussle over. The use of correlation on the data we have do not reveal

what socio-cultural factors are influential causes. But since climatic conditions do not fully explain and do raise contradictions, we suppose the other factors are modifying agents.

There is no striking regional pattern or patterns relative to mortality rates from cerebral hemorrhage, etc., among states. (See Fig. 7.) The highest rates are found in Maine and New Hampshire, next highest in Vermont, Maryland, Virginia, Ohio and Indiana. Low rates are scattered from Atlantic to Pacific Coasts and from Canada to Mexico. Rather obviously neither climate nor topography, temperature nor moisture, have paramount determinative influence. Statistical application of methods of correlation result in nothing at all significant. There is a correlation coefficient of 0.40 with a probable error of .08 between this death rate and per cent. of urbanism, showing that living in cities or some factor or factors in urban residence perhaps are causative factors. A more significant coefficient results from correlating hemorrhage death rates with the per cent. of population between ages of five and fifty-four, one of -0.51, with a probable error of .07. This would read that the greater the per cent. of inhabitants in that wide age period, the one with a uniformly low death rate generally, the lower is the mortality rate from cerebral hemorrhage. If the physician advised such patients to keep out of Maine and New Hampshire, the states with highest death rates from this cause, he should not do it because of climatic reasons, for they probably have little to do with the case. In fact, he would have little reason for giving such advice, since it is likely that the heavy migration of younger persons out of those states has left an exceptionally large portion of those who are in upper age levels and so who are especially addicted to attacks of cerebral hemorrhage. It is a biochemical rather

FIG. 7. MEAN NUMBER OF DEATHS PER 100,000 FROM CEREBRAL HEMORRHAGE, ETC., UNITED STATES, 1932–34.

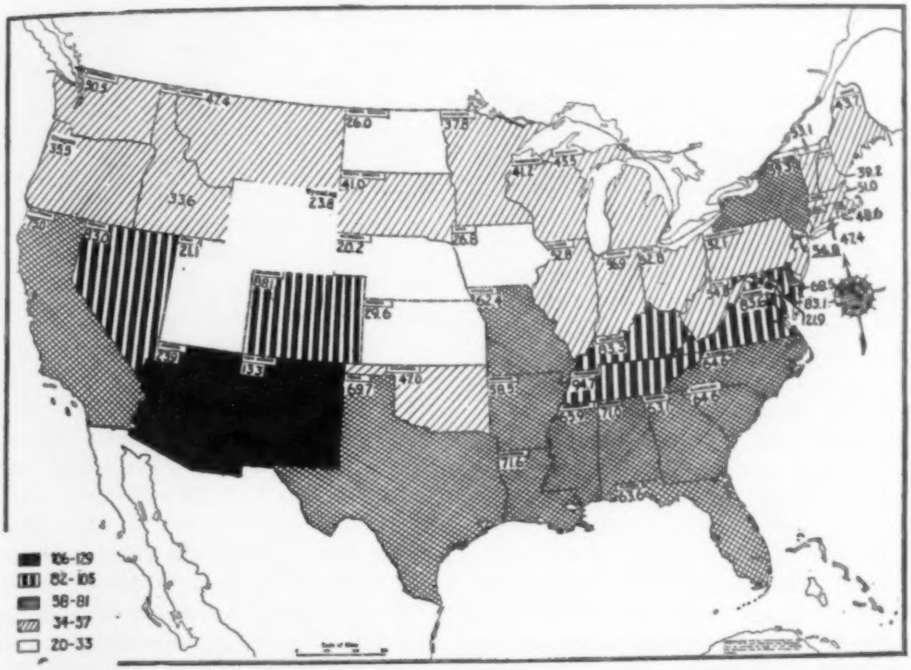

FIG. 8. MEAN NUMBER OF DEATHS PER 100,000 FROM TUBERCULOSIS, UNITED STATES, 1932–34.

than physical or cultural environmental matter.

Regionality shows up strongly in the spot-map of tuberculosis (Fig. 8). All the highest death rates from that disease, all the next highest, and most of the medium rates lie in states south of the northern tips of Nevada, Colorado, Missouri and Maryland. There is only one medium rate state, New York, north of that line. The six lowest rate states are Kansas, Utah, Iowa, Nebraska, Wyoming and North Dakota. The most southerly next lowest rate state is Oklahoma. On the surface, medical advice to tuberculosis patients as to location would be to avoid the low-rate states, probably for climatic reasons.

Yet here again, as in previous instances, most contradictory situations crop up. Here are states identical in class of rates but fundamentally and widely differing in climatic conditions: Nevada and Colorado on one hand and Maryland, Virginia, Tennessee and Kentucky on the other. There are also North Dakota and Utah, Montana and Oklahoma. New Mexico, with a rate of 133, and Arizona, with one of 239, stand highest in rates, yet these high rates are only indirectly due to climate. Tuberculosis patients repair there to avoid the disease and just happen to die there and so run the state rate up. What is true of them is only less true of Nevada and Colorado. How largely migration to supposedly favorable climates affect the death rate of other states is indeterminable. Evidently low temperatures are not unfavorable to tuberculosis, since it is the northern states generally which show low rates and the state with the lowest mean temperature, North Dakota, is only fourth above the lowest tuberculosis death-rate state.

Coefficients of correlation are favorable to the idea that climatic conditions have a good deal to do with distribution

of tuberculosis mortality rates. That for temperature and tuberculosis death rate is 0.58, while that between the latter and precipitation is 0.59, the probable error in each case being .06. Thus the tuberculosis death rate varies directly with temperature and the amount of precipitation, remembering the notable exceptions which were indicated.

Due to mutilation of the spot-map of pneumonia, the visual picture of death rates from that disease can not be presented. But the states have been grouped according to rate classes, and the mode of spread noted. Seven of the nine geographical divisions of the United States with eight states and all climates are represented in class one; nine divisions, twenty states and all climates in class two; five divisions, twelve states and all climates in class three; three divisions, seven states and all climates in class four; and the District of Columbia alone in class five. There is no large block of states with similar rates anywhere and no distinctive regional pattern. Further, in testing the matter by correlating the series relating to temperature, precipitation, per cent. of urban population and per cent. of inhabitants in ages five to fifty-four, no coefficient which is at all near significance is obtained. The conclusion is inevitable that no region or climate in a large way appears advantageous for pneumonia patients. However, one might think that the three areas, Arizona, Delaware and the District of Columbia, whose rates range from 100 to 120, are either disadvantageous in some way or that afflicted persons flock there to live or for hospitalization. On the other hand, the physician might have good grounds to advise his patients to seek relief in any one of these states whose pneumonia death rates are under sixty, placed in order of ascending rates from 48.5 to 57.8: Oregon, Washington, Kansas, Wyoming, Kentucky, South Dakota, Mississippi and Nebraska. It is to be noted that hot and cold, dry and wet climates are present in this favored group of states.

TWENTY-ONE COLLEGES EXAMINE THEMSELVES

In advancing the frontiers of learning, the physical, biological and social sciences have overthrown many of the old authorities and have challenged the ideas, the values and the beliefs that gave order and coherence to the older scheme of knowledge. The present chaotic character of higher learning is the direct result of the breaking up of the established pattern of culture. There are some who believe that the broken pieces can be reassembled. For them education's whole duty is to conserve and transmit the cultural inheritance from the past and to remain loyal to the traditional disciplines of liberal learning.

There are others who would make a negotiated peace. They do not ask for a return to the old order, but they would like to correct the unbalance between technical training and liberal culture. They believe that science and scientific method should be counterbalanced by philosophy, religion, literature and art. . . .

There are still others who have complete confidence in scientific knowledge but lament the backwardness of the social and biological sciences as compared with the magnificent advance in our control of inert matter and our knowledge of the physical world. For them the primary task of education is to explore the wilderness of social relations and the human mind. They believe that the answer to our problems is more knowledge. . . .

And finally, there are those who are excited by the riches of the new world, and embrace it for better and for worse. They welcome the advent of new patterns of knowledge and an indigenous American culture. They would let the dead bury the dead while they rally to the defense of the new order. For them there is no time to lose. The cause of freedom and democracy is in peril. It is only by education for democracy that the future can be made secure. They think of democracy not as a station but as a road, not as a status but as a process, not as a resting place but as a pilgrim's progress. They see in it man's brightest hope, the future's seal, the coming day of salvation. They have the conviction that this is the new integrating principle, the new way of life we must find and teach.—*William P. Tolley, The Educational Record, July, 1941.*

KARL PEARSON: FOUNDER OF THE SCIENCE OF STATISTICS

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THE death of Karl Pearson in 1936 ended the career of one of the most influential scientific figures of the present century. His influence has been due not to sharply defined and dramatic discoveries in science, but to the development of a methodology for investigating many phases of biological and social science with greater objectivity than had been possible before. There had been forerunners of this new methodology such as the early English school of political arithmetic, the German school of state-science and the French school of probability, but it was Pearson and his pupils who combined the principal ideas advanced by these earlier schools and founded the science of statistics as we know it to-day. The statistical method of investigation developed by Pearson and his school and subsequently expanded, refined and reoriented in some respects under the leadership of R. A. Fisher has been adopted as a fundamental part of the procedure of inquiry in many branches of social and biological science. Whether we look into the literature of genetics, eugenics, medicine, public health, agronomy, entomology, psychology, economics, quality control of industrial products or any one of many other fields, we find frequency curves, correlation coefficients, chi-squares, standard errors and other Pearsonian tools of statistics.

It is difficult to give even a rough indication of the extent to which Pearson's ideas and methodology have entered into the development of these various branches of scientific investigation without mentioning a few facts about Pearson's activities and the status of biological and sociological science at the beginning of his career. Born in 1857, he was trained in the traditional Victorian manner in mathematics and philosophy at Cambridge in the late 1870's. In 1880 he was made a fellow of King's College, which assured his financial independence for several years. The next five years represent for Pearson a period of intense intellectual activity and a great widening of his interests. Undoubtedly influenced by his father's profession, Pearson was called to the Bar in 1880 and established headquarters for legal studies in Inner Temple in London. During the next few years he made several trips to Germany, became interested in the history of the Reformation and German thought and social life of that period. Between 1882 and 1884 he delivered several series of lectures and wrote a number of articles on his findings in German historical research, all of which were later consolidated into "The Ethic of Freethought," and published in 1888. In this piece of work, we can see Pearson's youthful idealism shaping itself into "that faith of a scientist which formed the basic philosophy" of his life. At the same time he was collecting material on the German Passion Play, which was used later in "The Chances of Death." Despite his ventures into the social studies at this period, his mathematical talent was by no means idle, for he was busy writing papers on the motion of fluids and other topics in the mathematical physics of that time. In 1884 he was appointed to a professorship of applied

mathematics and mechanics at University College, London. Here we find him continuing his research in mechanics, as well as completing Clifford's "Common Sense of the Exact Sciences" and Todhunter's "History of the Theory of Elasticity," both of which were left in fragmentary form by the deaths of the authors. In addition to the scientific value of completing this work, it helped crystallize in Pearson's own mind many ideas regarding the fundamental concepts of science which were developed in a course of lectures given at Gresham College and later revised and published as "The Grammar of Science" (1892). This work is, and will probably remain for a long time to come, one of the classics in the philosophy of science. In it, he attacked the dogmatism of the past and stressed the need of eliminating from science any jurisdiction which theology and metaphysics may claim. He went a long way toward unscrambling many points of confusion which existed in nineteenth century scientific thought by discussing and developing the idea of the necessity of strictly limiting the domain of science to an objective description of the "how" rather than the "why" of phenomena, regardless of the nature of the phenomena. "The Grammar of Science" gives a remarkably clear picture of the scientific idealism which was to characterize Pearson's later work. The function of science to Pearson was "the classification of facts, the recognition of their sequence and their relative significance." To him "The unity of all science consists alone in its method, not its material." For his motto, he adopted the well-known words of Galton: "Until the phenomena of any branch of knowledge have been submitted to measurement and number it can not assume the status and dignity of a science."

There is little room to wonder that in his later years Pearson, so strongly bound to these philosophical principles, should have turned his attention to problems in such a variety of fields. Within a few years after his appointment to the professorship at University College we find Pearson, heavily influenced by W. F. R. Weldon and Francis Galton, beginning an extensive series of mathematical and statistical investigations into inheritance and evolution. Knowledge in this field up to now was mainly descriptive and had not been subjected to numerical treatment. The extent of Pearson's written contribution to the study of these problems is amazing. During the period 1893–1901 he published in the *Philosophical Transactions of the Royal Society of London* about thirty-five papers and memoirs on these studies and on the mathematical problems which grew out of them. It was in this program of research that he made his greatest contributions to statistical theory. He developed the theory of multiple and partial correlation based on normal multivariate populations, introduced curve-fitting by the method of moments, evolved his system of frequency curves, derived the famous Chi-square Test of Goodness of Fit, deduced many standard error formulas, and carried out many other investigations in theoretical statistics. Users of modern statistical tools familiar with Pearson's work who will stop to examine the concepts underlying the use of their methods will surely be impressed by the extent to which Pearson contributed to this body of tools. Of course much has been done in recent years in the further development and refinement of the mathematical tools of statistics, but without carefully considering the embryonic nature of statistical method before Pearson's time, it is difficult not to overlook the full significance of his original work in mathematical statistics.

Pearson was so vigorous and unswerving in his scientific pursuits that

he was frequently involved in controversy. One of the most bitter controversies of his career arose over the biometrical versus the Mendelian approach in genetics. The Mendelian hypothesis regarding the mechanism of heredity was rediscovered in 1900 after Pearson had advanced to a rather late stage in his biometrical study of inheritance. Some of his papers and views were severely criticized by Bateson, a vigorous personality of the Mendelian school, and this opened the controversy which lasted for four or five years and resulted in a virtually complete divorce between the approaches of the two schools to the study of heredity. This was perhaps unfortunate because it now appears that the Mendelian and biometric methods are, to a considerable extent, of a complementary nature rather than fundamentally incompatible. One of the results of the Bateson controversy was the founding of *Biometrika,* a journal which has played a leading rôle in the development of statistical methodology.

In 1906 after the death of Weldon, who had inspired Pearson in his study of heredity and evolution, Pearson began to turn his attention from the general principles of heredity to Galton's infant science of eugenics and to the creation of a research institute where the ideas and techniques which Pearson had been advancing in rapid succession during the previous years could be carried on under more stable conditions and built into an independent and established branch of science. The result of his efforts was the foundation of the Biometric and Eugenics Laboratories, which were formed in 1911 into the Department of Applied Statistics. Thus in 1907 we find Pearson at the head of the Department of Applied Statistics, in charge of the Drawing Office for engineering students, giving evening classes in astronomy, directing two research laboratories and editing *Biometrika* and other series of publications. This was indeed an enormous task for one man and could have been done successfully only by a man possessing his power of concentration and his ability of rapidly shifting his mind and attention from one subject to another. It was not until 1911 that he gave up his chair in applied mathematics to give his full time to statistical studies.

To give even an outline of the research work initiated by Pearson in his laboratories between 1906 and the outbreak of the World War, is beyond the scope of this sketch. However, most of this work can be roughly classified according to three headings: (1) memoirs concerned with the collection and analysis of fundamental data regarding inheritance; (2) memoirs in which statistical methods were used in an attempt to throw light on important social and eugenic problems of the time; (3) contributions dealing with statistical theory. The research done in (2) involved Pearson in various prolonged controversies. Included in this group of research projects were studies of claims made by various organizations and societies, some of which were sponsored by the medical profession, on the prevention of tuberculosis, on the effects of alcoholism, on the eugenic betterment of the race, etc. Much of the literature issued by these societies was propaganda based on ill-founded facts or none at all, and it was this type of authoritative dogma that Pearson rebelled against in "The Grammar of Science," and which continued to irk him throughout his life. For example, one of the problems which Pearson investigated was whether there was any evidence that the alcoholism of parents had any marked influence on the mentality and physique of their progeny during childhood. His conclusion, based on data from Edinburgh and Manchester families, was that there was no marked influence of this kind. The publication of this result created a terrific controversy in which economists, medical men who had denounced alcoholism at some

time or other and platform orators of temperance organizations joined in a chorus of protest and criticism. Undaunted by these critics Pearson only gathered more evidence and challenged them to refute his conclusions scientifically. This is only one of many fights in which Pearson became entangled then and later.

The contributions of the pre-war period dealing with statistical theory arose quite naturally out of Pearson's many statistical investigations. Almost all this work has been published in *Biometrika* or as separate publications issued by the Biometric Laboratory with the financial assistance of the Worshipful Company of Drapers. One important phase of Pearson's program was the preparation of an extensive series of statistical tables, and the first significant achievement here was the completion of "Tables for Statisticians and Biometricians" in 1914.

The outlook for the work of the Biometric Laboratory early in 1914 was better than it had ever been: a new building had just been completed; lectures were well attended; able students were being drawn from various parts of the world; many projects were under way; a growing body of opinion in various branches of science was learning to appreciate the value of statistical methods. With the outbreak of the European war, this whole program was disrupted, although some of the work such as the editing of *Biometrika* and research in statistical theory was continued on a small scale. Pearson placed his calculating facilities at the disposal of the Government, and his new building was used as an extension of the University College Hospital for the wounded.

After the war, Pearson, now in his sixty-fourth year, resumed his program at the new Galton Laboratory with his characteristic vigor and capacity for hard work. A considerable number of new enterprises were started and successfully completed before Pearson's retirement in 1933. Among these projects we find, "The Tracts for Computers," dog-breeding experiments, work in anthropometry and crainometry, finishing the "Life of Francis Galton" which was started before the war, founding of the Galton Museum and of the *Annals of Eugenics*. It is difficult to realize that all this new work was carried on under the personal supervision of a man between his sixty-fourth and seventy-seventh years and was done in addition to his lecturing and editing of *Biometrika*. He resigned his chair in 1933 and continued some of his work in retirement until his death in April, 1936. His Department of Applied Statistics was divided into two independent units—a Department of Eugenics with which the Galton professorship would be associated and a Department of Statistics. The two new departments are now headed respectively by R. A. Fisher and E. S. Pearson.

In his recent biography entitled "Karl Pearson,"[1] E. S. Pearson has given a most illuminating and carefully

[1] E. S. Pearson, "Karl Pearson," Cambridge University Press (1939). This biography is essentially a reprinting of two long articles of the same title originally published in *Biometrika* in 1936 and 1937. Since these articles were written primarily for the readers of *Biometrika*, the emphasis has been placed on the scientific life of Karl Pearson. The book is well documented by letters, photographs and extracts from the work of Pearson and his associates. An interesting feature is the addition of two appendices which did not appear in the original *Biometrika* articles. The first of these contains detailed syllabuses of thirty lectures on the "Geometry of Statistics" and the "Laws of Chance" delivered by Pearson to a popular audience at Gresham College between 1891 and 1894. The second appendix was prepared by G. Udny Yule and contains a summary of subjects dealt with by Pearson in his lectures on the "Theory of Statistics" when Yule was a pupil of Pearson's at University College in 1894–96. The book also includes a partial bibliography of 122 articles, books and memoirs written by Pearson.

interpreted account of the motives, methods and accomplishments of his father. He has portrayed his father "as the historian, the writer on folk-lore, the socialist, the applied mathematician who discussed problems of elasticity and engineering . . . , as the author of 'The Grammar of Science,' as the biometrician, statistician and eugenist, as the teacher and the biographer." It is perhaps safe to say that Pearson's greatest contribution to science is not his work in any particular one of these fields, but it is the methodology which he has developed and illustrated again and again for handling problems in these and many other fields of a similar nature. He "has made the calculus of mathematical statistics a real factor of practice in vast fields of scientific inquiry."

AMERICA'S FIRST ATTEMPT TO UNITE THE FORCES OF SCIENCE AND GOVERNMENT

By Dr. JOHN WILLIAM OLIVER

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ONE hundred and twenty-five years ago this month (June, 1816), there was organized in Washington, D. C., a society for the promotion of the arts and sciences which came to be known as the Columbian Institute. So ambitious was its aim, and so pre-eminent were its leaders, that a brief review of this early scientific society may be of interest in times like the present.

The two leading spirits in organizing the Columbian Institute were Dr. Edward Cutbush and Thomas Law. At the opening meeting, June 1, 1816, Dr. Cutbush declared that the time had come in this young nation to organize the scientific minds of the country and place their services at the disposal of the government. "We would," he declared, "foster the arts and the sciences, and develop them for the benefit of all people. . . . There is scarcely an art or science that cannot be benefited by this society. . . . The science of chemistry is to be given special attention since it is considered the handmaid of the arts, and is intimately connected with almost every branch of human knowledge; the arts, agriculture, and manufacturing."[1]

[1] Richard Rathbun, *U. S. National Museum Bull.*, 101: 12, 1917.

This young scientific society immediately attracted the attention of leading men everywhere. Numbered among its members were John Quincy Adams, who for many years was America's greatest patron of science; John C. Calhoun, who had not yet become too deeply absorbed in the philosophy of states' rights; Henry Clay, who soon would be proclaiming his great American System; Andrew Jackson, who later was to view with alarm too much governmental interference in private affairs of any kind; Joel R. Poinsett, soon to rank among the leading scientists of the South; Charles Wilkes, who later was to gain renown as leader of the famous Southern Pacific Expedition, and who during the Civil War captured the British steamer *Trent*, and arrested Mason and Slidell as they were fleeing en route to England; William H. Crawford, Richard Rush, William Wirt, John McLean and others of equal importance.

The membership also included the names of fifteen United States Senators, twenty-eight Congressmen, six Cabinet members, two foreign members, army and navy officials and others holding important positions in the nation's capital. There were also doctors and lawyers, architects and bankers, educators

and gentlemen of the press. Almost everybody in Washington, if he was a man of prominence, belonged to the Columbian Institute. Aside from the resident members, there was a galaxy of honorary members, including Jefferson, Madison, Lafayette, Baron Cuvier and President Monroe. Outside of Washington, men prominent in science and learning were also invited to join.

Congress early granted official recognition to the Columbian Institute. By an act passed April 20, 1818, the Institute was legally incorporated, and given permission to hold its public meetings in the House of Representatives.[2] The Institute had no home for six years, but finally in 1824, Congress granted it permanent quarters in the Capitol—a large room under the library. In an act passed May 5, 1820, Congress further favored the Institute by granting it five acres of public land in the Mall, immediately west of the Capitol. The land was used as a botanical garden. An additional grant of land was voted May 26, 1824.[3]

The Columbian Institute got off to a good start. Its membership, as we have seen, consisted of many of the ablest men of the time. They were ambitious to serve their young, growing nation. Incorporated in the Institute's constitution were such notable objectives as that of collecting, cultivating and distributing the products of this and other countries, in order to promote domestic arts and manufactures; to collect and discover the various mineral products of the country; to invite communication on agricultural subjects; to obtain a topographical and statistical history of the different sections of the United States, their rivers, agricultural products, the climate and the arts and manufacture best suited to each particular region. Finally, when the Institute had collected a sufficient amount of important data on these various subjects, information that would be of value to the public, it was to be printed.

In addressing the Institute on January 11, 1817, Dr. Edward Cutbush, its first president, struck a popular note when he declared that there was scarcely an art, science or manufacture which might not be benefited by this association. He congratulated the Institute on having so many members who were able and willing to help in establishing botanical gardens, collect mineralogical cabinets, build up a library of science, and make this organization assume high rank among the scientific associations of the world. This country, he declared, afforded unlimited opportunities for new discoveries. He believed there were a sufficient number and variety of plants native to our soil, which if properly processed would make it unnecessary to import those now demanded by our physicians and our dyers. Our minerals should be used for something more than to decorate cabinets. The mineral resources of this country were waiting to be exploited. Metals, clays and marbles useful to the artist and the manufacturer, and pigments waiting to be manufactured from the ores, were lying untouched.

Members of the Institute were asked to help in introducing and cultivating coffee, sugar, various dyeing drugs, the cochineal insect, the silkworm, the sunflower, the white poppy and other plants. "Should we be enabled to introduce a single grain, or one grass, which will afford a greater proportion of nutrition than those we now possess, millions may be produced to our country." The files of the patent office, he declared, bore ample testimony to the genius which prevailed in all parts of our country. "Where genius and talents are respected

[2] *Annals*, 15th Cong., 1st Sess., 1777, *Appendix* 2594.

[3] *Annals*, 16th Cong., 1st Sess., 2585; and 18th Cong., 1st Sess., 787.

and rewarded, the arts and sciences will flourish, and the wealth and power of nations increase."[4]

The Institute's main purpose was to put science to work. Applied science, not theoretical science, was the chief aim. Its plant collections consisted of living plants—plants that could be used in the interest of medicine or for food value. Its collections of minerals were studied with reference to their usefulness in the arts, industries and manufacturing. Reports on agricultural experiments were solicited so that they might be passed on to all farmers and live-stock growers. In brief, here was the nation's first concerted effort, on a large scale, to organize the scientific knowledge of America and utilize that knowledge in a practical way. The titles of the papers read at the different meetings reflect this idea continuously. Papers relating to the culture of the silkworm, chemistry in agriculture, plant culture, improved ship-building, bellows for pumping foul air out of ships, the fixing of the first Meridian, the establishment of a system of weights and measures were read, and others of similar nature.

John Quincy Adams, while President of the United States, found time to attend several meetings of the Columbian Institute. He noted in his *Diary*, December 31, 1827, that he had that day attended the anniversary meeting, and was favorably impressed by Mr. Southard's address. "He (Mr. Southard) was about an hour in delivering it, and gave very general satisfaction. It was on the obligation of the government of the United States to patronize sciences. Southard argued the cause with great zeal and ability, urging it as a duty resulting from our situation among the nations of the earth, and recurring especially to the expressed opinions of Washington, Jefferson, and Madison."[5] President Adams went on to say that he himself gave a toast at this anniversary dinner, "To the Cause of Science," which were the first words of Mr. Southard's address.

It might be noted in passing that the Institute had no more loyal supporter at any time than President John Quincy Adams. Even after he was retired from the office of the president in 1828, he kept up his interest and with some regularity attended the meetings of the Institute. In his *Diary*, under date of January 16, 1830, he made extensive notes upon Edward Everett's anniversary address, which was given on that occasion. Adams described it as a literary, philosophical and scientific masterpiece. It was, "a description of the most important modern inventions and discoveries, and of the manner in which they had been made, with several interesting anecdotes relating to discoveries and inventors."[6]

Of all the papers read before the Columbian Institute during the twenty-two years of its history (Rathbun reports a total of 177), the one by the distinguished Edward Everett was the most significant. He gave this same address, with some modifications, on numerous occasions and before different groups in different sections of the country. It is worth noting a few of the main points found in that remarkable essay. Science and education, he declared, were as necessary to the artisan and the mechanic as to the philosophers. All useful arts should be carried to the highest point of attainable perfection. Many evils, he pointed out, had resulted to society, due to the lack of scientific knowledge. Some of these to be noted were: a lot of wasted effort in trying to convert the baser metals into gold; advanced scientific principles that prevailed in one section

[4] *Memoirs from Library of Congress; Papers of Columbian Institute;* printed by Gales and Seaton; 1817; pages cited, 2–29.

[5] Adams *Memoirs*, VII, 393.

[6] Vol. VIII, 171.

were unknown elsewhere; trades had become encompassed in "too much mystery" rather than science. Machinery of complicated parts could never be useful unless there were trained mechanics to operate them. Scientific knowledge is a necessary pre-requisite for those employed in "making or using labor-saving machinery,—those who are to traverse the ocean, construct the canals, build steam engines, work our mines, conduct large agricultural experiments, or set up manufacturing establishments."[7]

Looking to the immediate future, Mr. Everett declared that the older parts of the country which had been settled by the husbandmen and reclaimed from the state of nature, were now to be settled again by the manufacturer, the engineer and the mechanic. These sections had once been settled by the hard labor of human hands—now they will be settled by the labor-saving arts, by machinery, by the steam engine, and by internal improvements. All this would bring about significant social effects. Work in the Old World which had taken two thousand years to accomplish could be effected here in two hundred years. In those countries of the Old World, most of the prizes of life had been distributed by lottery of birth, whereas in America they were distributed on the basis of merit. An enlightened class of artisans, farmers and mechanics were the nation's best guarantee of its permanency. The perpetuation of such a social triumph would be cause for self-congratulation far beyond anything based upon mere material or political growth. "An intelligent class can scarce ever be vicious; never indolent."[8]

Mr. Everett cautioned his listeners not to think that they were approaching the end of scientific experiments. On the contrary, they were only in the beginning stages. Art and science are progressive—infinite in possibilities. "There is no end to truth, no bounds to its discovery and appreciation." His colleagues, fellow members of the Columbian Institute, were urged to join in this new undertaking of diffusing all useful knowledge among people everywhere. The elements of science should be imparted from kindred minds. The number of distinguished and useful men who are to benefit and adorn society are proportionate to the means and encouragement given to the useful inventions and discoveries. There had never been a time when greater improvements might be expected, provided inventors and scientists were given proper encouragement.

This paper of Edward Everett's is only one of several essays read before the various meetings of the Columbian Institute. But running throughout all the published addresses, there is one recurring note, namely, the time was at hand for putting science to work. This young nation would prosper only in proportion to the number of new and useful inventions. It was the duty of Congress to recognize this and give generous support.

But in spite of the efforts put forth by this little group of earnest men the Columbian Institute was never able to accomplish the things it set out to do. They had hoped, as Edward Everett had said, "to arouse the government to become the patron of the arts and sciences." And, although a few members persisted diligently in this aim, they never received much encouragement. Most of the members were too busy with other duties. Funds were not available for carrying on the work that needed to be done. The five dollars a year membership dues never amounted to more than $300 at any one time. Congress was never convinced of the need for such an organization. As the years passed, the Institute took on more and more the character of a learned society

[7] Edward Everett, *Speeches and Orations*, 1836, Ed., Vol. I, 249.

[8] *Ibid.*, 267.

rather than an organization whose chief aim was "to promote the arts and sciences." Learned treatises were presented, but few practical projects were undertaken.

However, there were a few tangible results that came from this first attempt to unite the forces of science and the federal government. A valuable mineral collection was assembled, catalogued and, to this day, reposes in the Museum of the Smithsonian Institution. A real beginning was made in botanical and horticultural work. Rare specimens of trees, shrubs and plants were collected from all parts of the country and used for experimental purposes. Also, the Institute aided in the projects of the American Pharmacopeia Society, and in the establishment of the United States Naval Observatory. Then, too, the Institute assisted in organizing and conducting the Southern Pacific Expedition, 1838 to 1842. And finally, more than any other organization, it had kept alive an interest in science throughout the decades of the 1820's and 1830's. By the time its charter expired in 1838, the new National Institute had been formed. The entire membership of the Columbian Institute was invited to join this embryo scientific group. This new organization in turn was soon to be succeeded by the Smithsonian Institution, now long distinguished as one of the world's most famous scientific societies. But due credit should be given to those who first pioneered in the field of applied science, and who launched this country into a study of its scientific and technological possibilities, rather than let it become a poor imitation of the literary and esthetic cultures of the Old World.[9]

[9] Selected references are found in Richard Rathbun's *Report, U. S. National Museum Bull.*; No. 101, 1917; G. Browne Good, *Annual Report U. S. National Museum, 1890–1891; Annals of Congress*, Gales and Seaton; 14th Congress to the 22nd Cong.; John Quincy Adams' *Memoirs*; Edward Everett's *Speeches and Orations*, Vol. I; and files of *National Intelligencer*.

THE MEANING OF MORALE

If it is to survive and at the same time be true to its own genius, democracy must reconcile enthusiasm with enlightenment, tolerance with conviction, strength with gentleness and unity with diversity. This problem of reconciliation is not artificial or gratuitous. It lies in the line of all genuine moral effort: to solve this problem is, in fact, morality itself. And there is a solution, hard though it be: to love the truth so much that one is hospitable to all its sources and channels, and respects the honest conviction of others; while at the same time loving humanity so much that one hates only inhumanity, and enjoys the equalities, the differences and even the rivalries which will spring from a wide sowing of the seeds of freedom. Men may be diverse in the lives they lead, and at the same time unified by a common love of their aggregate diversity. . . .

There is only one firm foundation for morale in a democracy, and that is to be, and not merely to feel, democratic; to enact and not merely to talk democracy. To be a democracy, and we may as well be honest about it, implies a continuous redistribution of power and privilege in the direction of a greater participation by the masses of the people. It also implies that the people, enjoying a greater power and privilege, shall cease to be masses. In the present crisis the democracies represent not only this creed, which is peculiarly their own, but the whole Christian, humanistic and cultural tradition of the Western World. If the crisis is to be met with a high morale, Americans must learn to consider themselves the united servants of these great causes. But if they are to sustain this conviction they must *experience* democracy, Christianity and humanity as realities. The more grave the crisis the greater the necessity of *being*, of *continuing* to be and of *becoming* that which one professes to be.—*Ralph Barton Perry, The Educational Record, July, 1941.*

SCIENCE AND HUMAN VALUES

By Dr. HOWARD E. JENSEN

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HUMAN civilization is the cumulative product of man's age-old faith that the universe he inhabits is intelligible and rational. It embodies principles of unity and order that his mind can comprehend and his will can employ in adding to the comfort of his body and the delight of his soul. All the material and spiritual achievements of humanity bear testimony to the validity of this confidence. Wherever it fades, the human mind lapses into lethargy and the will into impotence. Civilizations collapse when it perishes, and are reborn when it revives.

But this faith was itself a slow and hard-won achievement. For the gift of intelligence did not come to man like the latest mechanical gadget, accompanied by detailed instructions for its use. For untold centuries he looked out upon the universe in awed wonder, with no method of exploring its nature but his groping curiosity. His conception of his world was consequently vague and confused, and his control over it wavering and uncertain. With no effective intellectual method of winnowing the true from the false, he made many mistakes, and his knowledge consisted of a few grains of fact buried amidst vast accumulations of error. Myths, legends, magical formulae, empirical rules of thumb, these were his only intellectual store. Yet for hundreds of thousands of years they sufficed for the development of the rudimentary economic techniques of hunting, fishing, herding, agriculture and industry, together with social and political organization, and even morality, religion and the fine arts. Only four or five thousand years ago, in ancient Egypt and Babylonia, did there appear the first intimations of those methods of critical thought and investigation through which man was able at last to attain his vast intellectual achievements in philosophy and science. And therewith he acquired an increasing confidence in himself, and a growing faith that the world of nature constitutes, in part if not in whole, an intelligible order which his mind can comprehend and his will can command.

But for centuries after these first beginnings, man's methods of inquiry into the world about him were crude and bunglesome. Not until three hundred years ago can his most effective intellectual tools for investigating physical nature, the scientific method, be said to have been definitely constituted, and only since the dawn of the nineteenth century can they be said to have been intensively developed and employed.

Indeed, for a millenium and a half, from the collapse of the classical civilization of Greece until the dawn of the Italian Renaissance, the western world merely marked time in so far as the further development of scientific method was concerned. Men of the Middle Ages, however intellectually active they may have been in the fields of philosophy and theology, paid little attention to the scientific phase of the Greek tradition, and made no significant positive contribution to it. But the intellectual upheavals of the Renaissance and the technical problems created by the rise of capitalism and nationalism joined theory to practice, and wedded observation and experiment with imagination and reason into that harmonious union which provided the scientific movement with a new dynamic.

Into this new movement Francis Bacon threw himself with such vigor and

enthusiasm that he has often been called the father of inductive science. He was, however, rather its chief apostle, its leading interpreter and propagandist. The proper method of science, he said, is the wise interrogation of nature, and this consists in formulating problems so that they may be answered by a simple yes or no, and in devising experiments to produce the facts that constitute the answer. But for several generations the new method succeeded in imposing its program on astronomy and physics alone. Not until the close of the eighteenth century was it applied to chemistry, and not until the beginning of the nineteenth to biology. Finally, under the inspiration chiefly of John Stuart Mill in England and Auguste Comte in France, the idea became widespread that the methods which had won such notable successes in the study of the physical world might be applied to man and his institutions, to give him a control over human relations comparable to that already won over the physical and the physiological. The psychologist began to move out of the library of the philosopher into the laboratory of the scientist, and the economist, political scientist and lastly, the sociologist moved out of the study where they had previously sought to explain social conditions, and entered the world of practical affairs which they now sought to investigate and describe as first hand observers.

The scientific movement was accompanied by the greatest outburst of buoyancy and optimism that the human spirit had ever known. Bacon had insisted that the purpose of the new knowledge was exclusively to mitigate the sufferings and increase the happiness of mankind. And for nearly three centuries the triumphs of western civilization in mechanical invention, in medical improvement, in economic, political and social organization, seemed to prove him right. Populations increased, cities grew, wealth accumulated, death rates fell, the span of life lengthened, standards of living rose, museums and art galleries were founded, schools and universities flourished. Forecasting the course of the future from the time of the French Revolution, Condorcet declared that "from the observation of the progress which the sciences and civilization have hitherto made . . . we shall find the strongest reasons to believe . . . that nature has fixed no limit to our hopes." Only the destruction of the earth itself can put an end to the infinite perfectibility of man and his institutions.[1] And throughout the century following, publicists and men of affairs, with now and then a rare exception, united in this hymn to progress. Herbert Spencer wrote:[2]

> Progress therefore is not an accident, but a necessity. . . . The modifications mankind have undergone, and are still undergoing, result from a law underlying the whole organic creation. . . . As surely as the tree becomes bulky when it stands alone, and slender if one of a group; . . . so surely must the human faculties be molded into completeness for the social state; so surely must evil and immorality disappear; so surely must man become perfect.

In 1898 Alfred Russell Wallace described the hundred years just drawing to a close as "The Wonderful Century" and in 1919, F. S. Marvin referred to the period between the Napoleonic era and the close of the World War as "The Century of Hope." Even as late as 1920, Paul Haworth brought his study of the United States since the Civil War to a close with a chapter entitled "A Golden Age in History," while only twelve years ago, Herbert Hoover, in his campaign for the presidency, expressed his conviction that we are on our way to abolish poverty from the land, and to place two cars in every garage and two chickens in every pot.

Although it has long been apparent to thoughtful minds that science contains

[1] Outlines of an Historical View of the Progress of the Human Mind," p. 319, London: J. Johnson, 1795.

[2] "Social Statics," p. 80. New York: D. Appleton and Company, 1865.

little promise of fulfilling the hopes it had raised, it is only within the last decade that the common man has come fully to realize the extent to which his hopes have been betrayed. For the ultimate problems of our civilization are social and moral, and science, while it has placed new and powerful instruments in the hands of men, has done nothing to clarify the moral and social purposes which these instruments are to serve. Consequently the instruments, which in the hands of men of social intelligence and good will might have realized our hopes, are now being employed by the strongest and most ruthless to destroy them.

The betrayal of man's higher spiritual values by the machines he has himself created is nowhere more poignantly portrayed than in the motto of the British Broadcasting Company, "Nation shall speak peace to nation," promulgated in a world in which the radio has become man's most efficient instrument of speaking lies and war. It was the radio that laid down the barrage of propaganda that prepared the way for the ruthless aggression practiced upon China, Ethiopia, Spain, Albania, Austria, Czecho-Slovakia, Poland, Lithuania, Latvia, Estonia, Finland, Denmark, Norway, Luxembourg, Belgium and Holland. These sixteen peoples, nearly one fourth of all the independent nations of the world, have, within less than half a decade, passed under the yokes of conquerors made diabolically efficient by contributions of physics and chemistry to the arts of destruction. In the economic field science has enormously increased our capacity to produce, but it has also made our opportunity to consume more insecure. It has concentrated wealth and economic power into the hands of a few, driven a wedge between the farmer and his land, the craftsman and his tools, and made both dependent, not upon their own industry and thrift, but upon the vagaries of the market and the price system. Viewing the results in these two fields alone, economics and international politics, what hope remains that applied science will promote the higher values of man's spirit?

To this indictment the scientist has two replies: first, that if the findings of science are bent to such nefarious ends, the responsibility does not rest upon the scientist, but upon the practical men of affairs, the statesmen, the politicians, the captains of industry and finance. But this is only to plead guilty to the charge of Launcelot Hogben. "The education of the scientist and technician," he says, "leaves them indifferent to the social consequences of their own activities."[3] We may justly paraphrase a question raised by Charles and Mary Beard in another connection, Are they to regard themselves as the members of a privileged gild, entitled to go their own way without reference to the fate of society?[4] Rare indeed among scientists is the social conscience of the Swedish chemist, Alfred Nobel, who shrank back in horror from the uses of human destruction to which his production of dynamite had been put, and who devoted a considerable part of his life and fortune to the promotion of international peace, that the product of his genius might not continue to wreak havoc with mankind. Equally rare among inventors is the social conscience of the Rust brothers, of Memphis, Tennessee, who have refused to sell their mechanical cotton picker, but only license it for use, in order that its commercialization may not bring idleness and starvation to millions of farm laborers of the South, and who plan to use their profits to create a fund to relocate in industry the workers whom their invention may displace.

The second reply of the scientist to the indictment that science has been destructive of the higher human values is that science as such is morally neutral. It has

[3] "The Retreat from Reason," p. 3. London: Watts and Company, 1936.

[4] "America in Midpassage," Vol. II, p. 869. New York: The Macmillan Company, 1939.

no concern with value. It is interested in quantities, not qualities. It studies only what is, not what ought to be. It can tell us only what is true, not what is right or good or wise or beautiful or holy. For knowledge of these things we should turn, not to the scientist, but to the philosopher.

Even the social scientists have of recent years made common cause with the natural scientists in washing their hands of all concern with human values. The economist, the political scientist, the sociologist, we are told, must study a social situation as the astronomer studies a nebula or the biologist an organism, to describe what exists, and to predict, if he can, what must exist to-morrow, but that is all. He may study suicide, divorce, crime, poverty, unemployment, strikes, lynchings, war, but whether these things are good or bad he does not know. Any interest in their ethical implications, or any concern about human welfare, is scientifically taboo. He is a social technician solely. He can teach us efficiency in attaining our ends, but not wisdom in choosing them. He tries to learn, for example, how depressions are caused and how they may be prevented, but whether we should have bigger and better depressions or smaller and fewer, is a question of social ethics or social welfare, and he does not know. Lest this appear to be caricature, let us note a recent statement of a former president of the American Sociological Society:

> That there has been any recent, catastrophic breakdown in the social order is not immediately evident. There has been, to be sure, a marked increase in unemployment and economic distress: the percentage of the population that is unable to secure unassisted the minimum means necessary to continued existence is large and increasing. But this does not in any real sense represent a breakdown in the system; on the contrary it may equally well be taken as representing the culmination and flowering of the traditional social and economic order.[5]

[5] Quoted from *Social Forces*, 13: 203, December, 1934.

Under the pressure of this trend in sociology at least, if not also in economics, political science and history, it is as much as a young man's academic future is worth to show an interest in the ethical or welfare aspects of social problems, and many an intelligent young graduate student is frightened away from research upon problems of the most pressing human concern for fear of the effect upon his future prospects of appointment and promotion.

We might for the present accept this defense of the scientist, that science is concerned with what is, not with what ought to be, and that for knowledge of human values we must turn not to him, but to the philosopher, if the scientist were in fact such a humble person as this answer implies. For it reduces the scientist to the role of a mere servant of the philosopher, providing the means whereby we can realize the human values which the philosopher validates and clarifies. But the scientist is rarely so self-effacing. He is usually quite convinced that scientific knowledge is alone entitled to respect, and, emerging from his laboratory, he thrusts aside the work of the philosophers as worthless, and proceeds to formulate a view of human life and destiny in harmony with his own professional bias. Thus, R. K. Duncan, a former professor of industrial chemistry in the University of Kansas, has written:

> We believe—we must believe, in this day—that everything in God's universe of worlds and stars is made of atoms, in quantities x, y or z respectively. Men and women, mice and elephants, the red belts of Jupiter and the rings of Saturn are one and all but ever shifting, ever varying swarms of atoms. Every mechanical work of earth, air and water, every criminal act, every human deed of love and valor: what is it all, pray, but the relation of one swarm of atoms to another? . . .
>
> Now, whether we call the atoms God's little servants or the devil's agents, one thing is sure—that every action of every thing, living or dead, within this bourne of time and space, is

the action of one swarm of atoms on another, for without them there is but empty void.[6]

Here we have it clearly and baldly put: our human values, our acts of love and valor, our aspiration for goodness and beauty, are one with the belts of Jupiter and the rings of Saturn, atoms dancing in an empty void!

In such a world, man's belief that his choices are in any sense real, that he can engage in creative activity of any kind or contribute towards the realization of his ideals, that by taking thought and expending effort he can in any significant way modify the course of events, develop his personality or conserve and enhance the world of values—all these are vain illusions. As Dr. John H. Bradley has expressed it:

The desire to get somewhere is deeply rooted in the human heart. Man wants ends for his struggles, hopes and fears, where he fancies he will find peace. But nature has an entirely different point of view. . . . She has imposed a cyclic pattern upon the universe, whereunder all things are charged to go on for ever, but never to arrive.[7]

In such a world man should never "waste time looking for a purpose where probably there is none," but "let it pass."[8]

Thus the scientific movement, beginning with the assertion that it has no concern with human values, often ends by heaping contempt upon philosophy, which has. For the natural scientist, working in his laboratory with the basic conceptions of matter and mechanism and quantity, is all too prone to think of the entire universe outside the laboratory in these terms, and to assert, as do the writers already quoted, that all reality is material reality, that all causation is mechanistic causation and that all knowledge is quantitative knowledge. And, since the human values, truth, beauty, goodness, holiness, can not be weighed or measured, it follows that we can have no valid knowledge about them, and that they can be nothing more than illusions born of our desires. As Joseph Wood Krutch has expressed it, either the light of science is somehow deceptive, or all the things we cherish are unsubstantial, all the values we pursue and all the principles we cling to are but shadows, and the universe, emotionally and spiritually, is a vast emptiness.[9]

This shattering of confidence in spiritual values is the most damaging blow that science could strike mankind. It has centered attention upon the tangible and the ponderable, exalted material possessions as the measure of human worth, and substituted comfort, excitement and entertainment for truth, goodness and beauty, as the supreme values of life. This concern of modern man with material things has left a void in his soul, and, shut up between the darkness of the birth from which he came and the darkness of the grave to which he goes, he can only fill the void with an increasing volume of material possessions and an increasing intensity of sensuous satisfactions. It has made of life a system of tensions, a continuous succession of strains which is never followed by relaxation.

But these facts, disconcerting as they are, provide no basis for a fundamentalist tirade against science as such. The structure of modern science stands as the greatest achievement of man's intelligence; the technological inventions which it has made possible remain as the greatest accomplishment of his hands. But a science which assumes that its basic concepts of materialism and mechanism and quantity exhaust the possibilities of dependable knowledge has ceased to be science, and degenerated into a

[6] Quoted from Max C. Otto, "Things and Ideals," p. 182 f. New York: Henry Holt and Company, 1924.

[7] SCIENTIFIC MONTHLY, 30: 457, May, 1930.

[8] C. C. Furnas, SCIENTIFIC MONTHLY, 31: 50, July, 1930.

[9] *Atlantic Monthly*, 149: 162–72, February, 1927, and 151: 372, March, 1928.

dogma which has betrayed civilization. For if we can discover no dependable knowledge of the good life which the intelligence must recognize as valid and the will as obligatory, our civilization can not survive the forces which science has let loose within it. For unless the principles of moral and social obligation can be recognized as binding upon the impulses of every individual and the interests of every group because they are rationally valid, there remains no way of settling the conflicts that rage between individuals, economic classes, political parties, religious sects, nations and races, but by the appeal to force and violence. "Let them fight it out," say those who have lost their faith in the capacity of intelligence to discover rational principles of social order. But they have not been able to fight it out in ten thousand generations, though they have destroyed innumerable civilizations in the attempt. And they can not fight it out in ten thousand generations to come, though still more civilizations perish. For though a nation can by force set its house in order, it can not by force establish order within its house. And though a nation can by war force another nation into submission, it can not by war force another nation into harmony with itself. Order and harmony come by agreements mediated by reason, not by treaties imposed by arms. When interests are repressed by force, they remain as occasions for new conflict; only when they are adjudicated by reason are they set permanently at rest.

But never in the history of Western civilization has confidence in a moral order based upon reason been weaker; never have moral principles been more cynically flouted, never have fraud and falsehood been more brazenly flaunted, never has force been more ruthlessly wielded. Never could less reliance be placed in the solemn treaties of nations or the pledged word of statesmen. For what can we expect of a civilization nourished intellectually on the bouillion cubes of science without the vitamins of value but that it should suffer from moral rickets?

One may, of course, be reminded of Malachi's despairing cry, ringing down twenty-five centuries of time from ancient Judea, "Why do we deal treacherously every man against his brother, profaning the covenant of our fathers?" He may be reminded, moreover, of Aristotle's cynical advice to the tyrant in the Fifth Book of his "Politics," of the political immoralism of Machiavelli's "Prince" or of Thomas Hobbes' observation that man is unto man a wolf, and that his natural state is a war of each against all. The answer to this is fourfold.

First, these are the laments of prophets and the observations of scholars, not the confessed policy of statesmen. Not until the rise of the contemporary dictators have the responsible heads of states while still in power publicly acknowledged their use of fraud and violence as regular instruments of political policy, as Mussolini, and especially Hitler, have done in their official publications.

Second, the areas of social life still under the sway of the ordinary human decencies have been so wide that heretofore the dictator has been compelled by public opinion at home and abroad strictly to follow Machiavelli's advice to his Prince that, though he need be neither honest nor generous nor just, he must always appear to be so.

Third, while it is true that deception and violence have always stood in the background of human affairs, they have most of the time remained there, to be brought into action only in moments of extraordinary crisis, but the modern dictators have made the crisis perpetual. Bismarck considered war the extension of diplomacy, but it has taken a Hitler to make diplomacy an extension of war.

Fourth, although deceit and cunning and violence have never been absent from

history, not until they became armed with the resources of modern science and technology could they on a scale so ruthless and colossal destroy all the human values which decent men prize. It is high time for all who call themselves scientists, whether physical or social, to make common cause with philosophy and the humanities in the defense of human values, and in the competence of scholarship and research to find a rational basis for them in human experience which all men must accept. For let there be no mistake about it, in the midst of the passionate social conflicts that rage about us, if scholarship and research are unable or unwilling to determine the ends of economics and politics by reason, economics and politics will determine the ends of scholarship and research by force.

Dictatorship is the legitimate fruit of our loss of faith in reason to discover dependable knowledge of human values. For if there are no universal principles of moral obligation which the minds of all men must recognize and the will of all men obey, one man's opinion of what is good and bad, right and just, is as valid as another's, and the only guides to human conduct that remain are the biological impulses of individuals and the vested interests of groups. But such an unrestrained conflict of impulses and interests must reduce the individual life to madness and the social life to chaos. So in the theory and program of nationalism the interests of the state have been made supreme over all other interests in conflict. When the interests of individuals and groups clash it is recognized that all lesser interests must yield to the common good. It is recognized that there can be stability and harmony within the state only in the proportion that principles of equity and justice are available to serve as a basis on which the conflict can be resolved, not by might, but by agreement. But nationalism recognizes no such general principles of the rational good, binding upon it in a conflict within the family of nations. Here the nation becomes the final judge of its own interests; it is under no obligation to consider the consequences of its policies upon other nations, and as a last resort, there is no other alternative than the appeal to war. In that event, the highest moral obligation of the citizen is to die for his country, right or wrong.

But the dictator sees no grounds for applying one set of principles to conflicts between nations, and another to conflicts within them. If self-interest is supreme, and reason is degraded to serve the ends of expediency in the one case, it is equally so in the other. Neither within the nation nor without can the reason discover principles which the will is bound to respect. Consequently, the human values, truth, goodness, beauty, holiness, justice, honor, right, are what the self-interest of the dictatorship pronounces them to be. The minister in his pulpit, the editor at his desk, the teacher in his classroom, the philosopher in his study, the scientist in his laboratory, all alike must prove and proclaim whatever the dictatorship requires; they must disprove and denounce whatever the dictatorship commands. As the Nazi courts have recently decreed, if an official commits a punishable act out of religious or other social motives, "these motives will be regarded not as attenuating circumstances, but as proof that he is involved in relationships which he values more highly than those which connect him with his superiors and with the state."[10]

The tragedy is that the greatest single intellectual influence in establishing this rule of unreason has been the dogma of natural science, that the only rationally valid knowledge is knowledge of things in their material and quantitative relationships and that all alleged knowledge of human values is mere opinion, born of self-interest and desire. If science is to realize its earlier promise, and to con-

[10] *Information Service*, p. 3. New York, April 20, 1940.

tribute to the enrichment of human experience and the mitigation of its ills, it must abandon this dogma and lend its influence to the re-establishment of confidence in the competence of the human mind to discover rational and intelligible principles of unity and order, not only in the realm of physical nature, but also in the realm of the human spirit.

The knowledge most desperately needed is knowledge concerning the principles of social organization and the ends of social action. No social science is adequate to this task that is descriptive only, that confines itself to exploring what is and predicting what will be. For human nature and human society are vastly richer and more complex in their potentialities than in their accomplishments. An adequate social science will of course begin with a careful collection of facts about how men carry on their common life together as families and communities, as economic classes and political parties and religious sects, as nations and races, but it will not stop there. It will pass on from this concrete knowledge of social actualities to the consideration of social possibilities. It will endeavor to work out all the logical possibilities of human association that rigorous analysis can disclose. It will formulate logically, in advance of the facts, the meaning and value which social life might contain if it were rationally ordered. If science is to contribute to human welfare, it must consider logical knowledge of the possibilities of social life as of equal importance with factual knowledge of its nature. For unless social policies are based upon fact they will not work; and unless they are grounded in logical principle they will not endure. A science which is adequate to our needs therefore will explore, both factually and logically, with a view to discovering both the actualities and possibilities of human existence, the five great fields of social relationships where civilized man now stands frustrated and defeated.

It will explore, first, the relations of men to one another as persons, in the family, the community and other face-to-face groups, where the extent of their frustration and defeat is measured by the statistics of suicide, mental and nervous collapse, divorce, delinquency, criminality and general personal maladjustment.

It will explore, second, the relations of men to one another as producers, or the problems of economics, where the extent of their frustration and defeat is measured by the statistics of unemployment, poverty, bankruptcy, business failure and recurrent depressions.

It will explore, third, the relations of men to one another as citizens, or the problems of politics, where their frustration and defeat is measured in terms of political corruption, machine domination and the general failure of our democracy heretofore positively to promote the common welfare which the Constitution of the United States places high among the primary purposes of government as stated in its Preamble, instead of giving its chief attention to the incidental and secondary rights of property which in the Constitution itself are tucked away in the due process clause of the Fourteenth Amendment as a sort of afterthought.

It will explore, fourth, the relations of men to one another as organized states, where their frustration and defeat stand disclosed in international anarchy, in the dread that stalks the lands, the horror that rains from the sky, the terror that lurks in the sea and the fear that rides the ether.

It will explore, fifth, the relations of men to one another as biological varieties, or the problems of race, where the measure of their frustration and defeat is revealed in the obscenities and cruelties of race prejudice, in riots, lynchings, pogroms and concentration camps.

It is a grim task, but beyond it there lies a great hope, the hope that by means of a social science that has become intelligent enough to extend its scope from social facts to social values, from a consideration of what is, to what might be and ought to be, we may formulate a rationally valid conception of the general social welfare, and develop a social organization adequate to mediate between the conflicting interests of human groups.

This is an old hope. Ever since the Greek philosophers began to reflect about man's life and destiny, it has been the unwavering conviction of the clearest intellects and the choicest spirits that the human mind is a competent instrument in clarifying the ends of our existence, and the human will is an active agent in attaining them. If this hope be false, no civilization can endure, and there remains nothing out of the wrecks of time for which decent men should care to live.

But there is no reason to believe that the hope is false. It is often said that man is not a reasonable creature, but it may be remarked that if this is really so, only by reason can the fact be known. And reasoners who employ reason to prove the incompetence of reason are interesting objects of study. As Irwin Edman has said, "Reason may indeed become a fetish, but so may distrust of it."[11]

But that a major part of our behavior wells up out of biological impulses or socially acquired interests of which we are unconscious or only dimly aware, constitutes a quite different problem. Here the daily experience of every civilized man bears witness to the competence of intelligence to produce harmony and order out of the clash of impulse and desire. Every day we bring the ends which we impulsively desire under the control of larger ends which we rationally recognize as desirable. Every day in the common decencies of life we adjust the claims of our personal and group interests to the interests of other persons and groups freely and gladly, because we rationally recognize the allegiance we owe as human beings to a life that is wider than our own. But as individuals and groups forge their way to economic and political power the rational control of intelligence weakens, the sensitive sympathy of the heart withers and the ruthless energy of the will abounds. From the destruction which this ruthlessness is now wreaking in our contemporary life, there can be no doubt but that the continuance of our civilization depends upon our ability to make this conception of the general social welfare as the only rational good so clear and convincing to man's intellect that in these wider areas of life it will compel the allegiance of his will.

Can we accomplish this result before our civilization is destroyed by the conflicts that now rage within it? We can not tell. If the odds against it seem heavy, we must remember that it has always been so. Life has always been fraught with risk and adventure, and the future with uncertainty. But if our present efforts fail, it is not unlikely that the same human nature which has pressed on through the repeated failures of vanished civilizations will persevere through future ages until it reaches whatever success its own capacities, the resources of physical nature and the limits of time will permit. For within the processes of social development, from the dawn of man until now, there has been operating the irresistible human impulse to be, to know and to do.

Our thought, then, ends in neither complacent optimism nor enervating despair. The outcome is doubtful enough that none of us dares be laggard, but hopeful enough to challenge us to the task with zest and high courage.

[11] "Four Ways of Philosophy." New York: Henry Holt and Company, 1937.

SOME OBSCURE RELATIONS OF ORGANISM AND ENVIRONMENT

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It has been suggested that I write a "reply" to Professor Ely's article appearing in The Scientific Monthly for February, 1940. This seems to me inadvisable for two reasons. First, there is to-day a very extensive technical literature of psychical research of which any brief summary for the purposes of discussion would be futile. Second, most of Professor Ely's article actually consists of a useful account of pitfalls in the subject, especially in the attempt to obtain results with platform performers.

But, since what is needed is more and better experimental research, the familiarity of scientists with some of the existing work may aid in planning critical or more penetrating investigations which carry us beyond the points reached. My task then is to attempt a compact account of certain types of experimental research which have been undertaken in relation to the problem of extra-sensory perception, hoping that the reader will look up the original sources and go further. My aim is simply to show that there is a *problem* which requires full analysis. The solution of the problem will be achieved not by debate but by scientific research.[1]

(1) In 1921, Dr. G. F. Heymans, renowned as an experimental psychologist at the University of Groningen in the Netherlands, undertook with two of his university colleagues, Drs. Brugmans and Weinberg, an investigation of the ancient and annoying problem of telepathy. Doubting the appeal to logic and metaphysics, the three men wanted to find out whether, under their own laboratory controls, as strict as they could make them, such a thing as telepathy did occur. There was at hand a young student of dentistry, Mr. Van Dam, who had the habit of going into relaxed or passive or more or less trance-like states. Such states had often been said to be productive of telepathic results. Why not try and see if this was the case?

Accordingly they made available for an experiment two rooms of the university laboratory, one directly above the other. They cut a large hole down through the floor of the upper room and through the ceiling of the lower room, and inserted double plate glass, permitting an air cushion between the two rooms. For use in the lower room they constructed a black cage in which their subject could sit. Looking down through the glass, observers in the upper room could see no part of their subject's body except the forearm and hand thrust through a horizontal slit in the cage at the level of the waist of the subject seated within. The subject was blindfolded. The question was whether, by thinking about it, the experimenters in the upper room could in any way influence the subject's choice as to certain numbers chosen by lot in the room above.

On a table in front of the cage was a rectangular board, about 12 × 9 inches, marked off into 48 squares in an 8 × 6 arrangement. The subject knew that in each experiment his task was to tap with his finger upon the board so as to indicate

[1] For the same reason I can not separate telepathy from clairvoyance merely because the philosophical difficulties seem to some writers greater in one case than in the other. Most of the good research has been done on the two together or in comparison of the two under similar experimental conditions. It is not philosophical expectation, I think, but experimental unity of subject matter that determines what belongs together in science.

one of the 48 numbers. After every few trials, an experimenter came in to the lower room and slightly changed the position of the board on the table so as to break up position habits of the subject.

All three of the aforementioned members of the psychology department acted as experimenters, but not all three at once. They worked one at a time. The task of the experimenter at any given session was as follows: First making sure that the blindfolded subject was in his cage and that his arm was extended through the horizontal slit and outstretched toward the board, he was to draw cards by lot to determine for each experiment a number from 1 to 48 inclusive. He switched out the lights, went over to the glass partition, looked down through the hole at the subject's arm, and willed that he should move a finger to the designated number. In view of the possible danger that an experiment would be prematurely terminated when the subject accidentally touched the right number, the rule had been established that the subject must tap twice at a given point when he had made his decision. From the charts and photographs supplied in the publications, it appears that the distance from the glass window to the hand was about four and one-half feet.

The foregoing is the "two room" procedure. In another procedure, used half the time, the blindfolded subject and board were as before, but the experimenter entered the lower room and tried to will the movement of the finger while gazing at it at short range.

A total of 187 experiments were performed. The routine statistical procedure gives us 1 chance in 48 of success by random guessing, so that by chance 4 of the experiments should have been successes. Actually, 60 were successful. Those in the "two room" procedure were better (34 successes in 80, as against 2 expected) than those when the experimenters entered the lower room.

With reference to the magnitude of errors, the data are instructive. The errors by 1-square displacement are commoner than those by 2-square displacement. These are commoner than those by 3-squares, so that there is a tapering off of guesses as the magnitude increases —almost a normal curve of errors around the correct hit as the central tendency.[2]

Most striking in this investigation are two lines of attack upon the physiology of the process. First, we said above that Mr. Van Dam had a tendency to go into relaxed states. The experimenters naturally wished to make use of such a condition in two ways, first to *augment* the relaxed states to study the effect, and second, to *measure* as precisely as possible how deep the relaxation really is. The first purpose was accomplished by giving 30 grams of alcohol. Out of 29 alcohol experiments, 22 were successes, interpreted as the action of alcohol usually is interpreted, in terms of "inhibition of an inhibition," reduction of tensions and the like. Second—and this was regarded as so important that it takes up almost the entire space on the long second report published by the Dutch investigators—the galvanometer was used to measure the electrical responses of the body. The galvanic skin reflex, or psycho-galvanic reflex, long known to experimental psychology, was put to use in a form characteristic of laboratory work and curves offered in the experimental report to substantiate the major generalization which runs as follows: The periods of greatest physiological passivity, which were found best in the telepathic experiment, can be detected objectively.

These investigations are published in the *Proceedings* of the First and Second

[2] Wishful behavior by which experimenters might count as hits those instances in which the tap was on the line between two squares might spuriously add here and there to the total, but even if this occurred in every trial in a chance series so as to allow all squares adjoining the right one to count as hits, the total would still be vastly below the reported total of hits.

International Congresses of Psychic Research held at Copenhagen and Warsaw respectively. They were read to these congresses by Dr. Brugmans. Subsequent correspondence shows that Mr. Van Dam turned to other things, "lost interest," and "lost his power," ceased to score significantly, and that the investigators, having nothing more to add and nothing to retract, decided to let the case stand as it was. So far as I can ascertain, nothing more on the subject by this method has been published by any one.

(2) Believing that uniformity in the material to be used through various experiments is important for many reasons, especially for quantitative comparison of one long series with another, J. B. Rhine, of Duke University, initiated in 1930 and to-day continues work with the five standard symbols, circle, rectangle, star, cross and waves. These may be printed on cards, shuffled, cut and concealed. When large masses of material are at hand, standard statistical procedures can be applied to the resulting distributions of correspondences between the subject's report (call series) and the actuality ("target series"); and control series can be obtained by independently shuffled and cut decks as well as by machine preparation of material. The cards are usually screened, often removed to a distance. Their order may be at the time unknown to any one, the stack of cards lying on a table or in a box; or the distant experimenter may gaze at each card as he comes to it, proceeding downwards through the deck. Different methods, different sizes of stimulus symbols, etc., and different subjects may be compared.

One of the central problems was the effect of distance. Accordingly one of the regular subjects, Mr. Pearce, went over to a room in the Duke University Library while the experimenter, J. G. Pratt, established himself with a deck of the cards in the Physics Building 150 yards away, in a room facing away from the Library.[3] He shuffled the cards face down, then cut them and put them in a face-down stack on a book. Pearce proceeded to call the cards "down through," from top to bottom, series after series. His record, and Pratt's record, were independently submitted to Rhine, scored and photostated. The hits, by runs of 25, are as follows: 3, 8, 5, 9, 10; 12, 11; 12, 11, 13, 12. The expected number (by chance), is 5; a score of 12 or better should occur about once in 700 runs.[4] The odds against such a result of random sampling (chance) are in the billions. A second such series was run under the same conditions but with the experimenter and cards 250 yards away in the Duke Medical Building, and the scoring level was again such that an experimenter should not expect to see it in a lifetime.

In all, four such long distance series with Pearce were done, as shown in Table I; each may be compared with the "same room" condition (Group E).

TABLE I

Group	Conditions	Number of trials	Average
A	Physics building and library .	300	9.9
B	Medical building and library .	1100	6.7
C	Physics building and library .	300	7.2
D	Physics building and library .	150	9.3
E	Same room	900	8.2

A good deal has been written about the possibility of recording errors which might increase the number of hits. I went through the above in the photostats and found one error. It was the omission of a hit.

(3) In 1935, Rhine was asked to lecture on his current investigations before a faculty and student group at Hunter

[3] J. B. Rhine, "Extra-Sensory Perception," 1934; *cf.* also, *Jour. Parapsychology*, 1: 74–76.

[4] There is a slight sigma correction which may at times be useful because of "linkage"; it can under certain unusual conditions raise the sigma from 2.00 to 2.04; it can not appreciably affect high critical ratios.

College in New York. He gave a brief account of his methods and results. At the close of his report, a member of the faculty, Professor Bernard F. Riess, remarked, in effect, "Either you didn't use the methods you described or you didn't obtain the results which you report." Rhine smiled and remarked, "In other words, I'm a liar." Riess replied, "I didn't say that." Rhine said, "The only way in which you will reach any convictions regarding my own work will be through your own independent repetition of such experiments." Riess took the challenge. A student in one of his classes reported that she had a friend in White Plains who could "do this sort of thing," *i.e.*, get impressions of concealed material. Accordingly, after a very considerable amount of trouble, arrangements were made for a long series of experiments to be done each evening at 9 o'clock, the subject being at her home in White Plains, Dr. Riess at his home a quarter of a mile away, on the other side of a hill. After shuffling a standard deck of 25 E.S.P. cards, Riess began at 9 o'clock looking at the card which was on top, and, proceeding at the rate of one per minute. Turning over each card when ready for the next, he proceeded through a deck of 25, immediately following with another 25 so as to give 50 one-minute trials for the evening. From time to time the subject sent in reports of impressions recorded in this experiment. These were placed in Riess's desk and nothing whatever was reported to the subject. At the end of 1850 trials, the subject had to terminate the series.

The relation of theoretical to empirical distributions with E.S.P. cards under control conditions, *e.g.*, matching one deck against another, is so close that it is sufficient to say that a score more than 4-Sigma above mean chance expectation is exceedingly rare. I have, for example, never seen such a score in a large block of control data in the course of years of work on this problem. The actual distribution of hits made by Riess's subject is given in Table II. Since mean chance expectation is 5 and Sigma is 2, a score more than 4-Sigma up would be above 13, *i.e.*, it would be 14 or better. The reader will see that the subject maintained a very much better score than this, hitting the 18's, 19's and 20's with almost monotonous frequency.[5]

TABLE II

Run	Hits	Run	Hits	Run	Hits	Run	Hits
1	5	21	21	41	16	61	18
2	7	22	20	42	21	62	18
3	10	23	19	43	22	63	19
4	12	24	20	44	17	64	18
5	15	25	18	45	16	65	17
6	8	26	14	46	18	66	18
7	16	27	15	47	19	67	19
8	13	28	15	48	21	68	20
9	18	29	16	49	20	69	20
10	21	30	12	50	19	70	20
11	11	31	19	51	16	71	19
12	15	32	21	52	21	72	20
13	19	33	22	53	23	73	21
14	24	34	24	54	19	74	21
15	21	35	20	55	17		
16	21	36	18	56	22		
17	22	37	22	57	21		
18	24	38	21	58	18		
19	25	39	19	59	15		
20	24	40	19	60	14		

Much has been written about the nonchance order of the "calls," or guesses, made by a subject. This is a very pertinent issue. Calls arise from a multitude of psychological factors in the organism, and are of course not a random series. The problem, however, is not the statistics of the call series; it is whether the order in the series of calls agrees consistently and repeatedly with the order of shuffled and cut decks at a distance (the "target"); the correspondence of the two is the very thing requiring investigation. In this experiment the subject made use of the five symbols with approximately equal frequency.

After a period of ill health the subject was persuaded to try another short series of 250 trials; she scored at the chance level. Merging the two series, while not according to ordinary scientific procedure since the conditions were different, would leave the chance problem unaf-

[5] The Riess reports appear in the *Jour. of Parapsychology*, 1937, I: 260 *ff.*, 1939, III: 79 *ff.*

fected. A single score of 22 or more would not be expected in continuous work through a century.

There are two kinds of comments which I have often heard on the Riess experiment. One relates to the possibility of recording errors. As far as I know, no one but Mr. Taves and myself has actually checked through Riess's original call and target sheets. In the course of 1850 calls we found one error. The other question has to do with Dr. Riess's veracity. This was the very question which was raised by Dr. Riess himself with reference to Rhine's report, and has for 50 years been repeatedly raised. I am aware that sooner or later the same will be said about me, because our own work has also given results which we can neither explain nor "explain away." To prove any one's veracity is to resort to further testimony which is also suspect, so that we are quickly involved in an infinite regressus. Science does not waste time on pseudo-legal problems of this sort; the discussion is sterile. If such experiments can in time be repeated with constantly improving procedures until ultimately every critic is satisfied and until the conditions governing the phenomena are clear, well and good. Till then, they may seem unused blocks, foreign bodies in the tissues of science, which can neither be used nor ejected. The future research will decide what they are.

(4) Effort in recent years has been directed to developing a simple fool-proof procedure not requiring the use of long distance but excluding all possibility of sensory cues or rational inference as to probable card orders, and reducing accidental errors in recording to the lowest possible minimum. Though the question of fraud on the part of experimenters can never be settled with mathematical certainty, the difficulty can be partially resolved by arranging that at least two experimenters independently record the data, lock them up, and require a third party to check them. This combination of experimental safeguards has recently been developed at Duke, and is exemplified in a report by J. G. Pratt and J. L. Woodruff in the December, 1939, issue of the *Journal of Parapsychology*. The subjects, tested one at a time, sat on one side of the experimental table separated from experimenter and cards by a vertical screen. Fastened to the back of the screen, *i.e.*, away from the subject, were five "key cards," of the five denominations already mentioned. At the end of the table away from the subject was the experimenter, who shuffled and cut a standard deck of 25 cards, holding them face down beneath another, inclined screen. It was then the task of the subject to poke with a pointer at one or another of five positions beneath the edge of the vertical screen, thus instructing the experimenter where to place the card which at the moment was at the top of the deck. The subject was by this procedure to *match* the top card with the key card which was fastened above the indicated position on the back of the screen; the performance was motor, not sensory. The correspondences, if shuffling is adequate, may be treated by the ordinary mathematics of the binomial, and if the shuffling is not ideal randomization, there should still be only chance relations between call orders and "target" orders except in so far as a causal principle, a behavioral linkage of calls and stimuli, is present. The key cards were obtained afresh by further shuffling and cutting for each experiment, being supplied by another experimenter and not shown to the experimenter who handled the cards during the experiment. The hits were counted and recorded independently by the two experimenters after each run of 25, the records being placed in a box for each experimenter and later checked by a third person. The number of discrepancies between the two experimenters in the course of 2400 runs of 25 each was 3; where the origin of an error was

unknown the lower of the two scores was used.

Thirty-two subjects took part in the procedure just described, with results yielding 489 hits beyond expectation. The chi-square method gives a p value of .000078 (random sampling would yield as high a deviation seventy-eight times in the course of a million experiments). A cross-check or *empirical control*, comparing call orders against other target orders than the one actually aimed at gave a result within ordinary limits for random sampling.

The main purposes of the experiment just described were to test the effects of *size* of stimuli and to test the effects of *habituation* to a given set of material. Within the limits set by four sizes varying from $\frac{1}{16}$ inch to $2\frac{1}{4}$ inches, size made no significant difference. Habituation effects, however, were marked. Average hits on the first occasion on which a given size of material was used were 5.39 per run; for second and third runs slightly less; thereafter not significantly deviating from the expected 5.00 (such habituation effects are an old story, but not previously so carefully examined). The point is stressed only because the question is often very reasonably asked: "Why go on repeating these studies unless your experiment serves to disentangle the significant variables, working toward the ultimate laboratory control of the phenomenon?" It is just such control that most contemporary studies aim to achieve.[6]

Space has limited this paper to a consideration of four experiments. All the data of each such experiment have, however, been included. There are many more experiments to be found in the literature. But the issue is not a question of "piling up" data. It is a question of determining by further and ever better work a system of functional relations between certain classes of objects and the perceptual and motor responses to them. As in other phases of science there is no place for gaping at mysteries or exorcising unexplained data.

The reader who is interested to follow the subject might first consult the original sources cited here; then run through the *Journal of Parapsychology* since 1937; then read J. L. Kennedy's "Methodological Review of Extra-Sensory Perception,"[7] then read the elaborate survey of experimental data and critical discussion in the recent volume by Rhine, Pratt, Stuart, Smith and Greenwood, "Extra-Sensory Perception After Sixty Years."

One word about names. The title of this article was chosen so as to be noncommittal as to ultimate interpretations. There are various names for these unexplained types of data. Emphasizing the relations of organism to stimulus, one may use the term *perception*. *Perception* is an "interpretation of a stimulus situation"; the interpretation is "correct" when there is a functional correspondence between socially accepted names for objects and the names given by the observer. When the receptor processes of the organism bear no known relation to the perceptual process, a purely operational definition, "extra-sensory perception," may be used. It is a neutral term, involving no hypothesis. There are, to be sure, hypotheses now proving serviceable in the guidance of research, of which a few have been suggested, but this article can not undertake to recount them more fully.

[6] A question that is constantly asked is this, "Where else besides Duke have positive results been obtained?" I hesitate to answer it because giving a list of universities may convey to some readers the sense of an "argument from authority," and this is out of place in science. Good work may be done in a bad university, bad work in a good university. Least of all should I want the reader to conclude that the individual university "vouches for" a result, any more than I should myself "vouch for" a result of any sort from any laboratory.

[7] *Psychol. Bull.*, 36: 59 *ff*.

THE SCIENCE OF CORNELIUS DREBBLE

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In the first decades of the seventeenth century Francis Bacon challenged a closed body of doctrine by asking a question. Few men in the preceding three hundred years had dared to oppose the standards of Aristotle. In a series of unexpected attacks, Bacon smote the scholastics hip and thigh, divided their ranks, drove them over the hills. During the century that followed the schoolmen made creditable but forlorn attempts to repair the disaster wrought by Bacon's appeal to induction. Through the years they were forced to continue reluctant withdrawal before new forces. At the end of the century Isaac Newton presented the world with an exact demonstration that the universe is one harmonious machine. Between the twin achievements of Bacon and Newton lamps of aspiration had been lit in innumerable laboratories. The Royal Society had been founded. Boyle and Harvey gave courage and elation to an England seeking a place in the newly robust circle of European science.

The course of the new science was undoubtedly aided by the work of a number of men, none of them in the first rank of scientists, who contributed their unspectacular mites to the brave crusade. They accepted and defended the formulae of emphatic protest against obscurantism. They helped to create a new "climate of opinion," sceptical and derisive, corroding the ancient fetters of authority.

One of these was Cornelius Drebble. In some respects he was to make polluted contributions to the science of his age; in others he was to prove himself a consummate fraud. Yet he did pour scorn on the intellectual detritus of the preceding ages. His critical spirit was sharp; his inventive genius was continuous. For a generation he marched behind Bacon and some, at least, of Bacon's precepts he made his own.

The early life of Drebble is hidden beyond the mists of three centuries. There is evidence that he was a student of the famous Goltzius, master engraver of Alkmaer. It is probable that he executed an engraving of the city of Alkmaer in 1597, a work that appeared in a book published in 1747 by the Dutch historian Boomkamp. However this may be, Drebble soon sought a wider arena for the exercise of his inexhaustible energy and curiosity. In 1608 he published a little volume, "On the Nature of the Elements." Here he discussed the manner in which the elements "cause the wind, the rain, the lightning and the thunder." In the Peiresc collection there is an anonymous French translation in manuscript. In 1621 Peter Lauremberg published a Latin translation at Hamburg. A German translation appeared in 1624 at Erfurt and two later Latin editions were produced in 1628 at Geneva and Frankfurt.

Most widely quoted of all the references to the early activities of Drebble is the curious *Kronÿcke von Alcmaer,* published in 1645 by Cornelis van der Woude. There it is recorded that Drebble was tutor to the young prince of Austria and later councilor to Ferdinand II. When Prague fell in 1620 to the armies of Frederick of Bohemia Drebble was said to have been taken prisoner, released as a result of Dutch and English intercession, called by golden persuasion to the court of James I of England.

At least a part of this biography we must dismiss as fiction. As early as

1609 Drebble was established in England at Eltham Park, far from the board of Ferdinand. From the young Prince Henry he received gifts of value of £40 during the year 1610. From the king himself it seems likely that he received permission to use an apartment at Eltham. Here the exile from Alkmaer succeeded by his ingenuity in making his name known to most of London. His age was of course an age of credulity, and the state of physical science was crude. These facts help to explain the emergence of Drebble as an alchemist, magician, empiric, professor of the black art. By observation, experience, mechanical skill and arrant knavery Drebble persuaded large groups of the public that new truths could be brought to light by those who followed the star of the new scientific principles. To some Drebble became a "deservedly famous mechanician and chymist"; to others he remained a charlatan.

It will be readily imagined that at a time when the foundations of scientific belief were becoming fluid, when a new scale of values was being insinuated into the teachings of the learned, when society was losing the firm grasp upon knowledge built by the great schoolmen the occasions for the impressive demonstrations of Cornelius Drebble were numerous and inviting. They were particularly inviting to one of a genial and energetic temperament who could easily lay foundations of friendship and who sought a position of influence and authority.

The first, and certainly to contemporaries the most impressive, of all the devices of Drebble appeared in 1609. He presented to James I a perpetual motion machine. A contemporary describes it as "a glass or crystal globe, wherein Drebble blew or made a perpetual motion by the power of the four elements." In methodical obscurity he continues:

> For everything which by the force of the elements passes in a year on the surface of the earth could be seen to pass in this cylindrical wonder in the shorter lapse of twenty-four hours. Thus were marked by it all years, months, days, hours; the course of the sun, moon, planets and stars. It made you understand what cold is, what the cause of the *primum mobile*, what the first principle of the sun, how it moves; the firmament, all stars, the moon, the sea, the surface of the earth, what occasions the ebb flow, thunder, lightning, rain, wind, and how things wax and multiply.

Then ensued the consequence that Drebble had probably foreseen. To view this wonder at Eltham came people of all classes. The Prince of Wirtemberg made a special journey to gaze upon the creation of Cornelius Drebble and to leave his royal words of admiration. Ben Jonson alluded to the popular interest when he caused Morose to exclaim in "The Silent Woman," "My very house turns round with the tumult! I dwell in a windmill! The Perpetual Motion is here, and not at Eltham!"

The strange machine that moved continually "without the help either of springs or weights" attracted also the attention of the Englishmen of science. Thomas Tymme published in 1612 a "dialogue philosophicall wherein nature's secret closet is opened." In his preface Tymme sets before his readers "A most strange and wittie invention of another Archimedes which concerneth Artificial Perpetual Motion immitating Nature by a lively patterne of the instrumente itself, as it was presented to the King's most royal hands." Tymme believed that in some fashion Drebble had "extracted a fiery spirit" (or perhaps "scintillula animae magneticae mundi") and thus maintained the motion of the machine. In 1628 good Bishop Wilkins called the Eltham device "a chymicall experiment" and there permitted the problem to rest.

It must have been disconcerting to Cornelius Drebble to discover that the popular appeal of his invention was not easily translated into money. But such

appear to be the facts of the case, for we find a petition addressed by Drebble to Prince Henry in May, 1612. In this petition Drebble declares that the Lord Mayor has refused him permission to hold a lottery. He pleads that he has no other means of subsistence and begs the influence of Prince Henry with Lord Treasurer Salisbury for leave to have a lottery beyond the jurisdiction of the city. He also sends a petition to Salisbury, explaining the proposed conditions for his lottery.

In the course of a few years, however, the fortunes of Drebble seem somehow to have become more firmly established. He has meanwhile invented a mysterious automatic musical instrument. He has also made famous a scarlet dye. In his own age tradesmen throughout Europe reaped large profits from its sale. Later Drebble was to give the secret dye formula to his son-in-law John Kuffeler and in the next generation it is known as "Kuffeler's colour," as readers of Evelyn will be aware.

There was another triumph which served to enhance the rising fame of Drebble. For the Prince of Orange he invented portable iron ovens, an event of importance in the development of mobile army units. To these real achievements he added others, some of them more questionable. Soon he reached the apex of his renown. His name was magic. A contemporary writer, reflecting upon the bewildering genius of Drebble, found no cause for litotes.

Aided by some instruments of his own manufacture, Drebble could make it rain, lighten and thunder at every time of the year, so that you would have sworn it came in a natural way from heaven.

By means of other instruments he could, in the midst of summer, so much refrigerate the atmosphere of certain places, that you would have thought yourself in the very midst of winter. This experiment he did once on His Majesty's request, in the great hall of Westminster; and although a hot summer day had been chosen by the King it became so cold in the Hall that James and his followers took to their heels in hasty flight.

With a certain instrument he could draw an incredible amount of water out of a well or river.

He made instruments by means of which were seen pictures and portraits; for instance, he could show you kings, princes, nobles, although residing at that moment in foreign countries.

He invented all these and many other curiosities too long to relate, without the aid of the black art; by natural philosophy alone, if we may believe the *tongues* of those whose *eyes* saw it.

There can be little question that Drebble was prepared on occasion to pass the discoveries of others off as his own. All his contemporaries recognized some excellent qualities in the Dutchman, but they declared that it was the pith of good sense to suspect him of the worst. For instance, the famous "lunettes de Drebels" were not his sole creation, even though they bore his name and attracted wide attention throughout Europe. Gassendi, Holstensius and Peiresc conducted a long correspondence upon the subject of the "lunettes" and to Gassendi Peiresc wrote "Et quand on voit du sable dans les lunettes de Drebels, on y trouve aultant de façon et de perfection bien souvent qu'aux caillous entiers, et aultres pierres plus precieuses et diaphanes." Yet Drebble, whom Gassendi called "ocellus eruditorum," was not responsible for the excellence that impressed Peiresc. There is also the fact that in 1619 Drebble displayed a new microscope to William Boreel, the Dutch Ambassador. Drebble described it as his latest invention. It had really been presented to him some months before as a gift from the Archduke Albert.

People liked to hear about the miscellaneous claims and inventions of this impressive scientist. They were well disposed to him, for the whole tendency was slowly beginning to flow strongly in the direction of that which was new, and that which was revolutionary therefore became that which was important. It was consequently to be expected that this man who had offered such a confi-

dent assortment of mechanical devices should have found the invention of a submarine particularly popular. And of his submarine "tryal was made in the Thames with admired success, the vessel carrying twelve rowers besides passengers."

A second contemporary continues:

> He built a ship, in which one could row and navigate *under* water, from Westminster to Greenwich, a distance of two Dutch miles; even five or six miles, as far as one pleased. In this boat a person could see under the surface of the water, and without candlelight as much as he needed to read in the Bible or any other book.

Robert Boyle was deeply concerned in the search for an explanation of the secrets of Drebble's submarine. In his "New Experiments Physico-Mechanicall" he attempts to answer the modern problem of oxygen supply.

> Besides the mechanicall contrivance of his vessel Drebble had a chymicall liquor which he accounted the chief secret of his submarine navigation. For when he perceived that the finer and purer part of the Air was consumed or over-clogged by the respiration and steames of those that went in his ship, he would, by unstopping a vessell full of this liquor, speedily restore to the troubled air such a proportion of vitall parts as would make it againe for a while good for respiration, whether by dissipating or precipitating the grosser exhalations or by some other intelligible way I must not stay to examine.

The success which attended the launching of the submarine marked the last appearance of Drebble as an idol of the populace. We possess, indeed, but fragmentary knowledge of the last decade of his life. We know that "Cornelius Drebble the Engineer" marched in the funeral procession of James I. We know that he labored for Charles I to produce "divers water-engines." We know that he was paid £150 a month as an officer of three fireships (to be used against the island of Rhé).

It is probable that one of his inventions remained a secret. John Kuffeler and John Drebble approach the government in 1662 to sell a secret of the great Cornelius. They request "a trial of their father Cornelius Drebble's secret of sinking or destroying ships in a moment, and if it succeed, for a reward of £10,000. The secret was left them by will to preserve for the English Crown before any other state." Allusion to this petition is to be found in Pepys and Evelyn as well as in the Calendar of State Papers. There is no record of the final decision of the government.

In 1634 Cornelius Drebble died in London. He was sixty-two years of age.

Great as were the sensations caused by the works of Cornelius Drebble the fact remains that he was not a giant in the annals of seventeenth century science. What he achieved has been largely forgotten. His meager share of fame has been a pruned paragraph in the history of scientific progress. And yet he has a title to the hesitant applause of the moderns, and this article is in part a baptism of approval. For Cornelius Drebble is an excellent symbol of a new age. He was one of the unsung disciples of Bacon and Harvey and Boyle. By slow degrees it was men like Drebble who spread abroad the notion that science was not a matter to be left to the schoolmen who had been first in the field. No longer should superstition flourish like fungus under the scaffold.

Cornelius Drebble may have been often a charlatan, frequently dishonest, but he hated passionately those who denied the precious principles of the new age and bowed before the authority of the fathers, with their "letters of opium on tablets of lead." He denounced the impotence and scientific sterility of the scholastics. He believed with Bacon that truth was not the daughter of authority but a secret slowly to be retrieved from the womb of time.

BOOKS ON SCIENCE FOR LAYMEN

AMONG IGLOOS AND ICEBERGS[1]

CONSCIOUSNESS of the frozen realm which lies to the north of us our readers have acquired through the books by Peter Freuchen, his "Eskimo," "Arctic Adventure" and "It's All Adventure," all of which appeared in the early thirties. The new decade has seen the appearance of Sydney R. Montague's "I Lived with the Eskimos," de Poncins' "Kabloona" (Eskimo for White Man) and Carlson's "Greenland Lies North." All these have been built upon some years of experience in association with the stone-age primitives that are the inhabitants of the cold and barren realm to the north of us, where life is fearfully hard and gaunt famine stalks through every winter.

The scene of Carlson's book is, like that of Freuchen's, Greenland, which is now in the public eye as our new outpost toward the Nazi world. De Poncins' narrative, like that of Montague, has to do with the Arctic fringe of British America, which is even less accessible and still less touched by civilizing influences.

Carlson went to the Arctic as a member of the scientific expeditions sent out from the University of Michigan, and for a full year he was in independent charge of an Arctic station north of 74° North Latitude. There he established himself with one white companion and with an Eskimo family as helpers and from which he carried out sledging expeditions with other groups of natives. He acquired their language and submitted to the unpleasant and unsanitary conditions incident to their hard life.

Through Carlson's book one learns of the almost unique physical conditions of this great northern island of Greenland, as well as of the interesting racial peculiarities of its human denizens. It is a tale of adventure which is full of interest as well as instruction.

"Kabloona" takes us to an extremely remote island of the Arctic Archipelago, King William Land, near the North Magnetic Pole. Strangely enough, the reader is nowhere told of the tragic history connected with this island, though it surpasses all other places in the North, for it was in King William Land that perished the 125 men of the expedition of Sir John Franklin, to rescue whom no less than forty separate Arctic expeditions were sent out before the facts were finally cleared up.

Gontran de Poncins is a French viscount who for fifteen months buried himself in this Arctic solitude, living most of the time in the igloos or on winter sledge journeys with some of the most primitive people on this earth. He had become disgusted with the life of his class and decided to become a wanderer in an attempt to find people who lived on better terms with their neighbors than those he knew best. As a result of this resolve, of his scientific training and of his facile use of the English language, he has put before us in this book the most illuminating study by one racial mentality of another. Even Freuchen, in spite of his two decades and more of association with Eskimos, has not given us so clear a revelation. As de Poncins himself has put it, "A good part of this book . . . is the story of the encounter of two mentalities, and of the gradual substitution of the Eskimo mentality for the European mentality within myself." A very crude and primitive type of sketch wholly in character the writer has used to illustrate his book, an outstanding contribution to anthropology.

WILLIAM H. HOBBS

[1] *Kabloona, A White Man Alone among the Eskimos.* Gontran de Poncins, in collaboration with Lewis Galantière. Illustrated. xii + 339 pp. $3.00. 1941. Reynal and Hitchcock.

Greenland Lies North. William S. Carlson. Illustrated. 306 pp. $3.00. 1940. Macmillan Company.

CAMOUFLAGE AND BLUFFING IN THE ANIMAL WORLD[1]

Cott's book is far more than a beautifully illustrated treatise on the colors and color-patterns of animals, though it is that among other things. It is an important contribution to theoretical biology, particularly as this relates to the origin of adaptations. The anti-Darwinian reaction of a generation ago, with its all-but denial of adaptation as a product of natural selection, has largely spent itself. To the surviving representatives of this school Cott's recent volume offers a serious challenge.

The author of this volume has exceptional qualifications for his task, being a naturalist with wide field experience in various parts of the world, a scientific photographer and a talented draftsman. I trust that I am not betraying a military secret if I add that Dr. Cott's special knowledge of the principles of camouflage have been utilized by the R. A. F. in the present war.

The title of this book is somewhat too restricted, in view of its contents. Many other means of protection are discussed besides visual ones, as for example such peculiar defensive mechanisms as those of the skunk, the porcupine and the rattlesnake. Likewise, much space is devoted to the highly appropriate behavior of both cryptically and warningly colored animals, without which their color-schemes would be largely futile. Our author, let us note, is as fully committed to the reality of warning ("aposematic") coloration as he is to that of the concealing type.

Cott's analysis of the principles employed by nature to effect concealment obviously owes much to Abbott Thayer, of some of whose ideas he makes extensive use. Thus vertebrate animals are commonly "countershaded," being most heavily pigmented on the more brightly illuminated upper surface, and much less pigmented below. Many animals, too, are "disruptively" marked, so as to obliterate their contours and to destroy the apparent continuity of their body surfaces. Needless to say, Cott entertains no such obsession as did Thayer respecting the universality of concealing coloration in the animal kingdom.

Among other principles of concealment discussed by our author are the elimination of shadows, in cases where these would bring an animal into relief, and conversely the pigmental imitation of shadows, in some cases where such markings tend toward disguising an animal's true shape. One of the most surprising of all the methods in nature's bag of tricks is a class of phenomena which Cott has termed "coincident disruptive coloration." Here we have patterns which "run out of all relation to, and frequently cut right across, the distribution of deeper structures. Frequently, as we have seen, they bridge the gulf between upper and lower jaws; or step over the pupil from one side of the iris to the other; or cross the slit of the eye from lid to lid; or span the space between the folded segments of the leg." Nature seems to have in view the visible appearance of these pigmental patterns, entirely regardless of underlying morphological considerations. Such "coincident" patterns are well illustrated in a number of the author's fine figures, and indeed it is likely that many readers have already been aware of the existence of these decidedly puzzling patterns, without having speculated on their meaning.

While it is possible that Cott has adopted too unreservedly an adaptive interpretation for some of these phenomena of animal coloration—particularly ones of the "warning" and "bluffing" type—he has assembled a mass of facts and arguments which are, on the whole, convincing with respect to his main thesis.

In the days of Darwin, and of the

[1] *Adaptive Coloration in Animals.* Hugh B. Cott. xxxii + 508 pp. $8.50. 1940. Oxford University Press.

earlier writings of Poulton, it was possible to challenge the natural selection interpretation of these phenomena on the ground that it was unsupported by evidence. At the present time, however, there is a very considerable array of evidence, both observational and experimental, bearing on this subject. It is one of Cott's valuable services that he has assembled much of this evidence in his recent volume. This relates not only to the now generally admitted survival value of concealing coloration, but to the more debatable value of "warning" coloration. The importance of both of these principles as factors in evolution seems at present to be reasonably well established. No denial of this claim can henceforth command respectful attention unless it commences with a refutation of such evidence as has been marshalled by Dr. Cott.

The reader (or at least this reader) would have been saved considerable time and patience had the page numbers of the plates in the volume been indicated in the frequent references to them throughout the text. It is necessary to mention, too, one regrettable omission on the part of the author, which we can not regard as deliberate. This is his failure to mention that his figure 18 on page 67 is a free-hand copy of an ingenious colored plate of Thayer's ("Concealing Coloration in the Animal Kingdom," Plate XI).

Despite occasional grounds for minor criticism, Cott's volume is a highly important and very interesting contribution to the literature of animal ecology and evolution.

FRANCIS B. SUMNER

THE STORY OF PLAGUES[1]

THIS is a first-class book. It is a combination of detective story, historical romance and scientific treatise. The stories it tells are of tragedies, mass deaths and the unraveling of the causative factors of diseases that have damaged and destroyed men for many ages. It wipes away the mists of superstition, clears up the clouds of fixed ideas or prejudices, and lets the reader see what has been done, how it has been done, and what will be done in the future if our studies are as fruitful in the future as they have been in the past.

Over and over again, as I turned the pages, photographs that I saw in Mukden of some of its alleys taken in that city in the early morning during the epidemic of some years ago of the pneumonic form of bubonic plague, came again into my vision. Scores of nude bodies, their clothing stolen by beggars, lay as they had been left to be picked up by the authorities. How often in the walled cities and garrison towns have human beings perished in the same way from diseases that were favored by herd living. Those who read "Plague on Us" will understand why public health should be supported and medical research encouraged. The human body as a reservoir of punishing organisms, the relationships of other living things to that body, and the way man and his society are winning in this struggle of one kind of life against another, are presented in a brilliant and sound manner.

I hope that Geddes Smith's book will become a "best seller."

RAY LYMAN WILBUR

MEDICINE THROUGH THE AGES[1]

THIS book consists of six lectures by as many authors, each a graduate in medicine. One lecture sets forth the position of psychiatry (mental disease) in modern medical practice; the other five are historical—the origin of some common ideas about health; health advice in Elizabethan England, and medical and surgical practices of that time;

[1] *Plague on Us.* Geddes Smith. Illustrated. 365 pp. $3.00. 1941. Commonwealth Fund.

[1] *The March of Medicine.* New York Academy of Medicine Lectures to the Laity. xii + 154 pp. $2.00. 1940. Columbia University Press.

ideas and practices current in Colonial America; the story of surgery and the story of insanity.

Dr. Walter C. Alvarez, of the Mayo Clinic, physiologist and clinician, finds in savage society the germs of origin both of scientific medicine and of quackery. Massage, bone setting and the giving of herbs, practices of the savage, were among the scientific ancestors of modern medicine; while the quackery of to-day is the lineal descendant of the primitive witch doctor's "control" of the spirits.

The wisdom of the first has been corrected and amplified down the ages. The second was born of ignorance, but has survived into our age of enlightenment as a cynical play on the credulity of the sick. The contrast drawn by the author is clear and entertaining. It will not be misunderstood as attributing to the practitioners in savage society the same separation of identity, of knowledge and ignorance, and of worthy and unworthy motives that exists to-day between the trained practitioner of medicine and his untrained or unscrupulous counterpart.

Dr. Sanford V. Larkey, historian, Johns Hopkins University, and Dr. Cecil K. Drinker, physiologist, Harvard University, picture the beginnings of modern medicine in England and Colonial America, respectively. Elizabethan England saw the beginning of health books of the family medical adviser type. It is interesting that these were more given to rules of prevention than to cure.

The charlatan was a recognized menace, and the licensing of qualified physicians was begun in this period to protect the public against him. The Dean of St. Paul's was given the responsibility of questioning the would-be practitioner to determine his fitness. Later the "companies" or "colleges" of physicians and surgeons took over the responsibility. In a day of beginnings, the barber could at the same time be dentist and surgeon; and the apothecary and the grocer were in the same guild. Blood letting, purging and baths were popular measures for treatment.

This was the day of the great plagues, and these stimulated the development of public health regulations by the state. Among the earliest were laws to protect the water supply, to keep the streets clean, and laws for the improvement of housing conditions.

The account of Colonial America by Dr. Drinker is based on the diary of Elizabeth Drinker, housewife. It covers 49 years, from 1758 to 1807. The extracts from the diary as quoted by the author are full of amusing incidents and reflect the keen sense of humor of Mistress Drinker. There is an account of the establishment of the first board of health in Philadelphia (in 1799); of a law forbidding slaughtering of cattle in the streets (1721); of the establishment of public bath houses in Philadelphia (1771); of the installation of a backyard shower at the Drinker home (1798); an account of an all-over bath, taken at great risk of health; of the cleaning out of a backyard "necessary"; of a nearby mineral well of great if temporary virtue. It was the province of midwives to care for women in childbirth, and a woman who employed a physician, a "man-midwife," was considered immodest. One new-born child out of three died.

Dr. Charles Gordon Heyd, surgeon, New York City, traces the development of modern surgery as essentially the history of the control of hemorrhage, of pain and of infection. Tying of bleeding vessels was known before the time of the Greeks, and was rediscovered by Ambroise Paré (1510–1590), son of a barber-surgeon. Blood letting was used three thousand years ago in treatment of "obsession with demons." It was a common treatment for a variety of ills, into the early years of the nineteenth century. Blood letting was early practiced by the monks, then after 1163 became the prerogative of barber-surgeons.

In the history of the control of pain the author tells of the discovery of ether anesthesia by Dr. Morton, and in the control of infection in surgery, refers to Dr. Oliver Wendell Holmes's deduction (1843) that the infection of puerperal sepsis is carried by dirty hands, the similar view of Semmelweis, Lister's experiments with antiseptic sprays (1867) and Halsted's introduction of rubber gloves. Other high lights in the history of surgery are given.

Dr. R. G. Hoskins, physiologist, director of research, The Memorial Foundation for Neuro-Endocrine Research, writes the history of insanity. Primitive man ascribed to events in nature motives similar to those that moved him, and inevitably, it seems, developed a belief in a spirit world. Dreams were an important factor, as here the dead walked again among the living. In line with such beliefs, the earliest explanation of insanity was that the sick person was possessed of an evil spirit. The earliest treatment was the incantations of the witch doctor.

Hippocrates repudiated the supernatural explanation of mental and other disease (460–475 B.C.) and classified mental diseases in a way that seems almost modern, but with the overthrow of Grecian culture by the Romans, the former concept regained its original authority. It was accepted in New Testament scripture and continued to be held during the middle ages by the Church Fathers, and by "the Phi Beta Kappas of the time." Even leaders as late as Calvin, Luther and Wesley continued to hold this view.

In accordance with this belief, treatment of the insane in the middle ages included the use of holy water, visits to holy places, fasting and prayer. Herbs, magic stones and incantations were recommended. The belief that beating and reviling the patient was equally punishing to the demon within led to use even of torture as treatment, and insanity came to be identified for all practical purposes with sin. "Bedlam" Hospital (St. Marys Hospital of Bethlehem) for the insane was one of the show sights of London.

The author traces the history of the more humane and rational treatment of to-day. In his account appear as pioneers of reform, Saint Damphna of Gheel, Philippe Pinel (1745–1826), William Tuke and, in America, Benjamin Rush and Dorothea Lynde Dix.

Dr. Karl A. Menninger, psychiatrist and author, writes an entertaining and convincing plea for psychiatry, the "Cinderella of Medicine." He emphasizes the interdependence of mind and body in the sick patient, and urges that the physician recognize psychological and social factors in his everyday practice.

Although addressed to the general public, the book should be equally interesting to the medical practitioner.

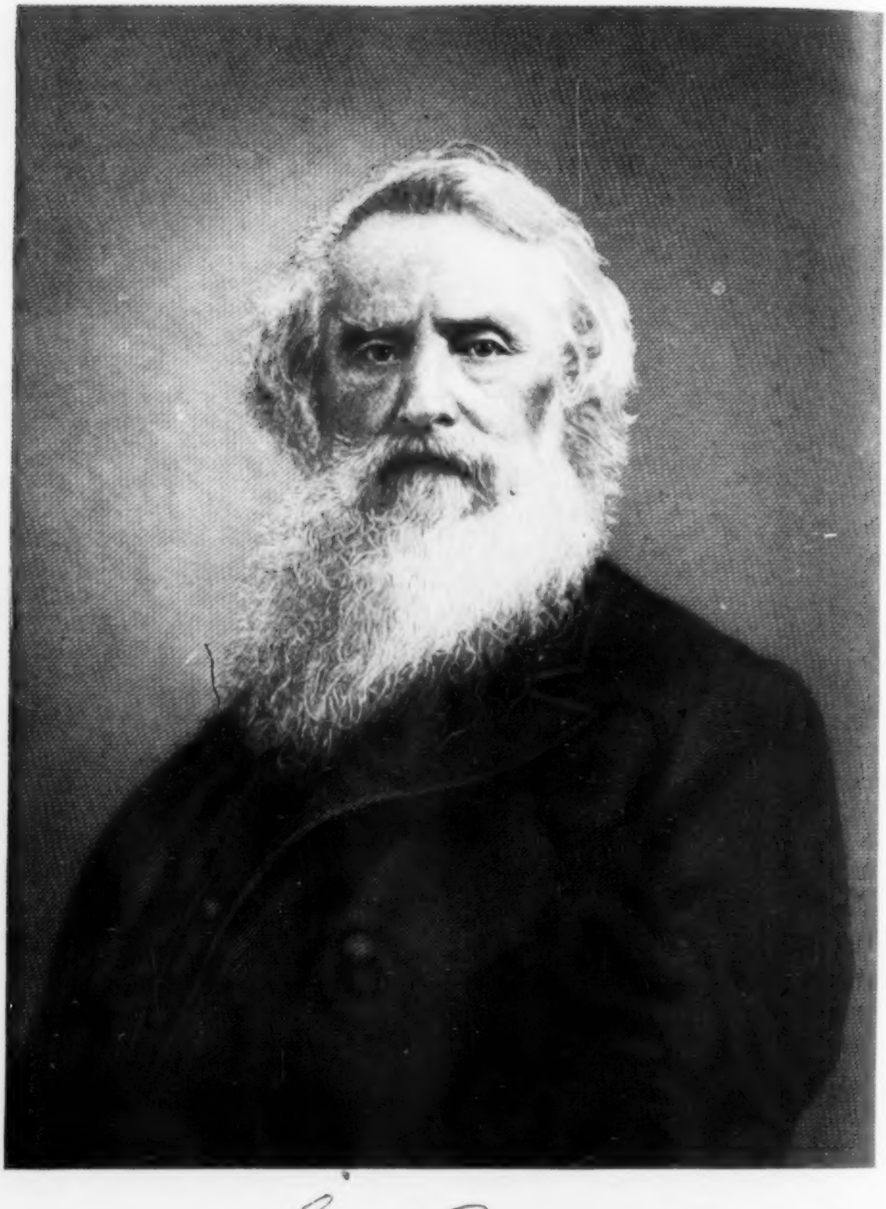
ERRETT C. ALBRITTON

THE DISCOVERY OF MAN[1]

THE subtitle states that the treatise is "The Story of the Inquiry into Human Origins," but we read later that it is "a tale which traces the growth of the twin sciences of archeology and anthropology from their beginnings among the Greeks to the present day," by a reader in classical archeology at the Oxford University. In reality the book is a very creditable historical presentation of the main facts relating to man's prehistory. Its six sections deal with: The beginnings of anthropological inquiries and observations among the Old Greeks; The decline of interest in the field; New worlds to search; The age of reason; Great discoveries, and Modern advances. American matters are not gone into with any great detail, but are dealt with sensibly, even as to the present Folsom illusion. The whole book is, moreover, very readable and deserves to be recommended to the public

A. H.

[1] *The Discovery of Man.* Stanley Casson. Illustrated. vi + 399 pp. $3.00. 1939. Harper and Brothers.



Saml. F. B. Morse.

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THE PROGRESS OF SCIENCE

SAMUEL F. B. MORSE, 1791–1872

SAMUEL F. B. MORSE and Michael Faraday were born in the same year, 1791, one hundred and fifty years ago. Faraday was born in London[1] and Morse in Charlestown, Mass. Both spent most of their lives in the study of electricity and electromagnetism, Faraday on investigations of the fundamental relations between them and Morse on the invention and perfection of wire telegraphy. One was the scientist; the other, the inventor.

The early surroundings of Morse were much more fortunate (if our ideas of what is a favorable environment for youth are sound) than those of Faraday. Morse attended Yale University, from which he graduated in 1810. He had the privilege of studying under Jeremiah Day and Benjamin Silliman, the latter the founder and for many years the editor of the *American Journal of Science*. He did not show, however, any exceptional taste for science during his student days. Indeed, he was more interested in art, and in the year following his graduation he went to England to study art. He was one of the founders and the first president of the National Academy of Design, which was organized in 1825.

Morse gradually became interested in electricity and in 1832 definitely set himself to the task of developing wire telegraphy. In the first year he made rough drawings of a method of accomplishing the desired results. After making his own models, moulds and castings, he completed his apparatus in 1836 and gave the first exhibition of its working on September 2, 1837.

The way of the inventor has often been hard. In 1837 Morse petitioned Congress for an appropriation to test his apparatus on a commercial scale and to demonstrate its value. He obtained his first patent in 1840, but no aid was forthcoming. Finally, in 1843, Congress passed an appropriation for a telegraph line from Baltimore to Washington, which was put into use on May 24, 1847. The first message was, "What hath God wrought!" In the meantime he had applied for a patent in England and had been refused. France granted him a patent but later expropriated it for its own use without compensation to the inventor. In 1858 several European governments, including those of Austria, Belgium, France, Netherlands and Russia, made monetary appropriations to Morse, who then took up experiments on submarine cables.

Many predecessors of Morse approached the idea of an electric telegraph, but did not follow it through with the construction of workable apparatus and the invention of a code. Among the better known scientists who saw, at least dimly, the possibilities of sending messages over long distances by electricity were Roger Bacon, Franklin, Newton, Ampère and Joseph Henry. Morse developed a system that functioned and, indeed, one that would carry two independent messages over a wire at the same time.

Fortunately for America the telegraph and steam railroads were both invented at the time the tide of western migration began to flow strongly across the Mississippi Valley, the Plains States and on to the Pacific Coast. These inventions made this rapid mass movement possible, and the mass movement made the rapid expansion of railroads and the telegraph necessary. The first continental telegraph line was completed in 1861. With the driving of a golden spike in 1869 the continent was first spanned by a railroad.

[1] See the August issue of THE SCIENTIFIC MONTHLY, page 183.

The development of both the railroads and the telegraph facilities has been phenomenal. To take care of the messages that are now sent from and received by more than 50,000 telegraph offices and agency stations nearly two and one half million miles of copper wire is required, exclusive of ocean cables. Much more would be required if it were not now possible to send several messages over the wire at the same time and with much greater speed than by the dot-dash-space method invented by Morse.

There are interesting and important human aspects to every scientific development. The telegraph has reduced the loneliness of the frontier and carried many happy messages as well as those that were sad. It gives employment to about 65,000 persons, all except the officers working only 40 hours a week. It provides opportunities for investment to more than 30,000 persons, the average investment being approximately $1,000 and none exceeding 2 per cent. of the stock of the largest telegraph company. It pays ten million dollars in taxes. It is an essential element in the infinitely complex and incomprehensible machinery of our present life. Samuel F. B. Morse! Rest in peace!

F. R. M.

THE UNIVERSITY OF CHICAGO CELEBRATION

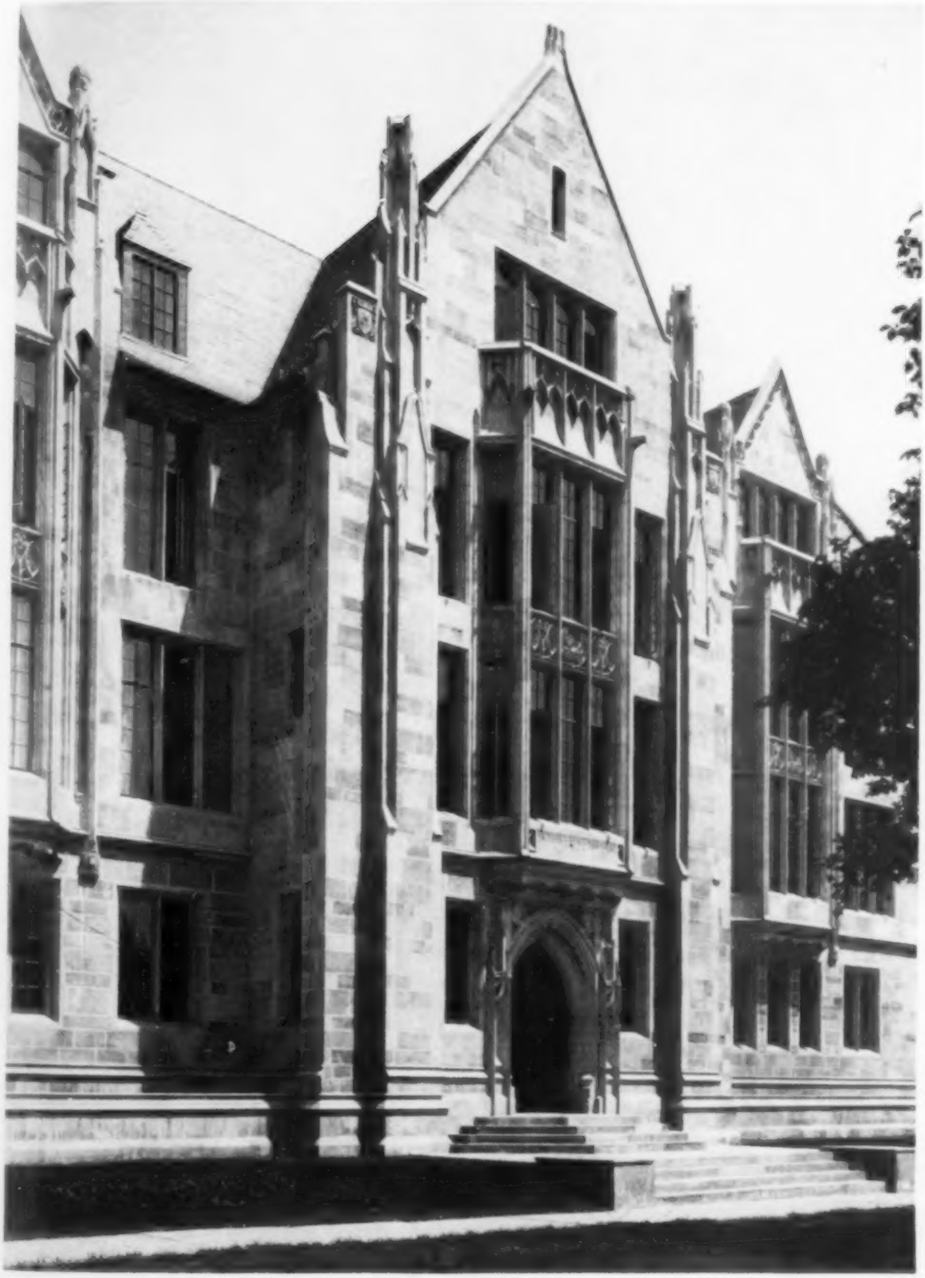
For the first time since its organization ninety-three years ago the American Association for the Advancement of Science will hold two summer meetings in one year. The first meeting this summer was held at Durham, N. H., in June in connection with the celebration of the seventy-fifth anniversary of the founding of the University of New Hampshire. The second will be held from September 22 to September 27, inclusive, at Chicago in connection with the celebration of the fiftieth anniversary of the founding of The University of Chicago.

Most of the programs at Chicago were organized by The University of Chicago under the general title "Fiftieth Anniversary Symposia." In addition to the symposia there will be thirteen general sessions at which distinguished scholars will deliver addresses in the fields in which they have achieved eminence. It is expected that they will be given honorary degrees by the university.

Thirty symposia under the general title "New Frontiers in Education and Research" will be presented during the week of the celebration and two will be held at earlier dates. The University of Wisconsin will join with the University of Chicago in a symposium on "The Respiratory Enzymes and the Biological Actions of Vitamins," the first part of which will be held at Madison on Thursday–Saturday, September 11–13, and the second part at Chicago on Monday–Wednesday, September 15–17. The other symposium to be presented in advance of the celebration week is "The Training of Biologists," which will be held on Thursday–Saturday, September 18–20.

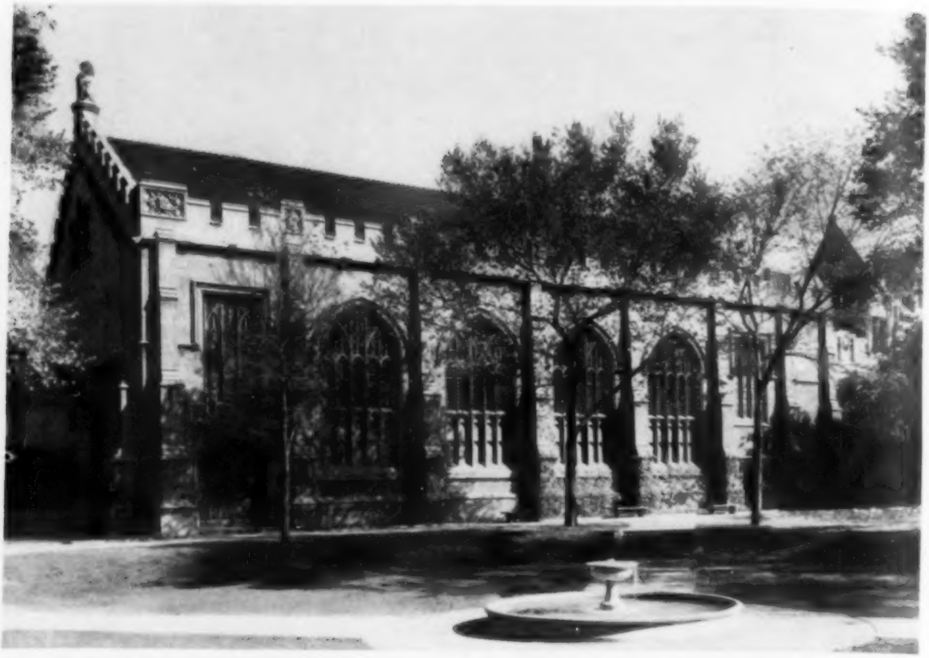
On the first day the chemists will begin with a two-day symposium on "Organic Chemistry," the biologists will hold one on "Growth and Differentiation in Plants," and the biologists and the medical scientists will start their discussion of "Problems in Aerobiology." The social scientists start their series of programs by a symposium on "The Public Social Services: Fifty Years of Progress"; the linguists, with "Approaches to Linguistics" and "The Editing of a Text"; and the educationists, with "Environment and Education." The programs are so extensive that, in order to finish in the week, in most fields they begin on the first day.

Perhaps the most extensive symposium is that on "Levels of Integration in Biological and Social Systems," a subject



BERNARD A. ECKHART HALL

WHICH HOUSES THE DEPARTMENT OF MATHEMATICS AND PART OF THE DEPARTMENT OF PHYSICS.



LEON MANDEL HALL OF THE UNIVERSITY OF CHICAGO
THE GENERAL ASSEMBLY HALL CONTAINING THE AUDITORIUM.

that was discussed by Dr. Ralph W. Gerard in the April, May and June, 1940, issues of THE SCIENTIFIC MONTHLY, which will be presented on Tuesday and Wednesday. Eleven scientists from five institutions will participate in this program.

Of all the subjects discussed, probably none has given rise to more varied opinions than "Cosmic Rays." It is highly appropriate that this subject should be considered at Chicago, for Dr. Robert A. Millikan, formerly a professor in the University of Chicago, is one of the earliest and foremost investigators of cosmic rays; and Dr. Arthur H. Compton, chairman of the Department of Physics in the university, is equally eminent in the field. Although these two distinguished Nobel Prize winners agree largely on the observational evidence they have quite different interpretations of what it may mean. Perhaps this subject illustrates as well as any other the general title of the series of symposia, "New Frontiers in Education and Research."

A symposium on a very timely subject is that on "Life at High Altitudes and Aviation Medicine." Although war has many terrible features, such as the destruction of life, the impairment of health and the more tragic dissolution of the finest human qualities, it has some good results. During the First World War much was learned about wounds, shock and malnutrition. During this war much human physiology is being learned because many aviators must fly at great heights. The observations and experiments are not made in airplanes but in airtight chambers in which atmospheric pressure can be lowered as required. Another interesting subject related in part to high altitudes is the transmission of low forms of life, both

plant and animal, by air for long distances. This question is a part of that discussed in the symposium on "Problems in Aerobiology."

Naturally the future of society is the subject of grave consideration. Its various aspects will be discussed in such symposia as "Civilizations in Transition," "The Place of Law in Society," and "The Place of Ethics in Social Science."

F. R. MOULTON

HISTORY SECTION OF THE SMITHSONIAN INSTITUTION'S NEW INDEX EXHIBIT

THE History Section of the Smithsonian Institution's new index exhibit comprises three wall recess panels labeled "civil history," "naval history" and "military history." In each recess a carefully selected series of objects exemplifies one of these three leading branches of the science of history as developed in a museum.

The central feature of the civil history recess is a bronze copy of Houdon's portrait bust of George Washington, flanked by a china plate and a silver tray, both owned at Mount Vernon by General and Mrs. Washington during the last years of the eighteenth century. In front of the bust is shown the small portable mahogany writing desk used by Thomas Jefferson when writing the first draft of the Declaration of Independence. Other objects to illustrate civil history are a silver teapot made by Paul Revere, another owned by Samuel Chase, a signer of the Declaration of Independence, and a series of United States coins and medals.

In the recess devoted to naval history an oil painting made in 1864 of the *U. S. S. Hartford* may be contrasted with an actual model of a First World War submarine chaser. A naval officer's sword and scabbard of the early part of the nineteenth century, naval medals of the War of 1812 and naval decorations of the First World War complete the naval history exhibit.

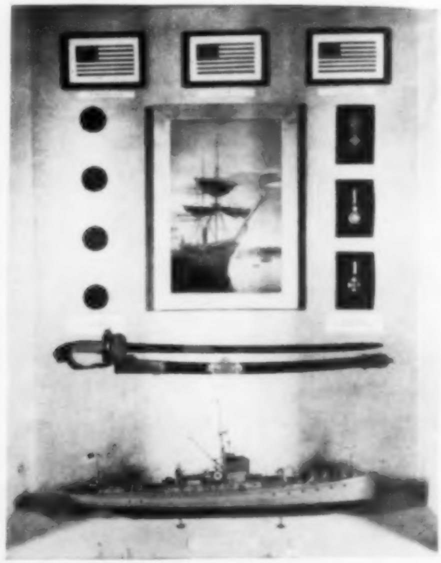
In the center of the military history recess is an oil painting showing the 77th Division marching down Fifth Avenue, New York, in 1918. Changes in styles of military headgear are illustrated by an enlisted man's cap of the period of the War with Mexico and a steel helmet of First World War days. Examples of Revolutionary War military medals and military decorations of the period of the First World War are also shown.

Across the top of the three recesses hang a series of nine small oil paintings representing the arrangement of the stars in the union of the United States flag at various times during the period 1777–1940.

The exhibit as a whole serves to represent the Historical Collections of the Smithsonian Institution, which are used not only for public exhibition but also for serious historical research. Those collections include also various other types of museum materials illustrating the lives and times of American historical characters and the material circumstances of the periods during which they lived. The emphasis placed on objects of a naval and military character in the present exhibit is in harmony with the spirit of the time and indicates the relative importance of the rôle played by materials of this character in the collections as a whole.

The historical collections brought together at the Smithsonian illustrate in an excellent manner the interrelationship between the civil, naval and military phases of American history and indicate clearly the rôles played by many eminent Americans in one or more of these fields of national service. Many mementoes of the careers of notable figures in American history both as soldiers and as states-

THE BUST OF GEORGE WASHINGTON
FORMS THE CENTRAL THEME OF THE EXHIBIT DEVOTED TO CIVIL HISTORY OF THE UNITED STATES.



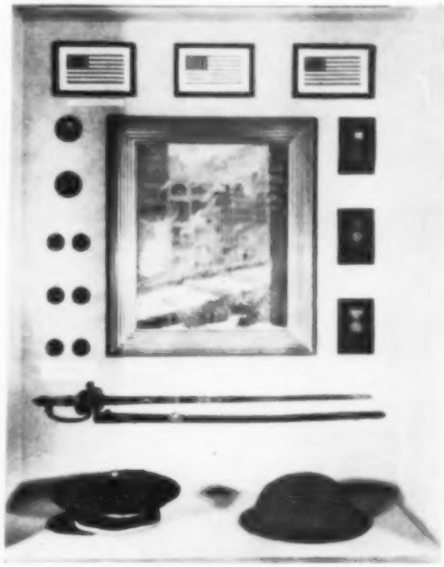
DECORATIONS, SWORDS AND SHIPS
ILLUSTRATE PERIODS IN THE HISTORY OF THE UNITED STATES NAVY IN THE NAVAL EXHIBIT.

THE HISTORY ALCOVE OF THE SMITHSONIAN INDEX EXHIBITS

men are included. The mementoes drawn from civil history represent the normal development of American civilization. The naval and military collections depict the development of the national energy in these two fields in times of national emergency in accordance with democratic processes and under the general direction of the civil authorities, as contrasted with that of the professional militarist.

Of the many types of media useful for the expression of these three phases of history in museum form, those of special importance in the field of civil history are such materials as china, glass, silverware, furniture, costumes, paintings, engravings, coins and medals; in the fields of naval and military history, arms, flags, uniforms, insignia, decorations, ship models and various types of naval and military paraphernalia.

THEODORE T. BELOTE



RELICS OF THREE WARS
THE REVOLUTIONARY, MEXICAN AND FIRST WORLD WARS MAKE UP THE MILITARY EXHIBIT.

NINTH SUMMER CONFERENCE ON SPECTROSCOPY AND ITS APPLICATIONS

THE Ninth Summer Conference on Spectroscopy and Its Applications was held at the Massachusetts Institute of Technology on July 21 to 23, inclusive. An indication of the current interest in spectrographic analysis of materials and in other applications of the spectrograph to scientific problems was the fact that advance reservations were made for all available seats. Attendance at the conference was limited to 250, it being desired to preserve the air of informality which has been found so conducive to animated discussions at previous conferences. A number of Canadian spectrographers were in attendance, as well as representatives from the Hawaiian Islands and other distant points.

It is difficult to point to any definite trend in spectrographic analysis as evidenced by the thirty papers presented at the conference. Steady progress is noted in the application of spectrographic methods to various problems of biology, chemistry, metallurgy and physics.

Among the papers which excited the greatest interest were those dealing with the development of new equipment. Professor O. S. Duffendack, of the University of Michigan, discussed the use of Geiger-Mueller counters in spectroscopy. A new spectrograph for the ultraviolet region was discussed by Dr. S. Jacobsohn, of the Gaertner Scientific Company, and an instrument for the infra-red was described by W. H. Avery, of the Shell Oil Company. Drs. H. B. Vincent and R. A. Sawyer, of the University of Michigan, described a new type of microphotometer for measuring line densities on the photographic plates used in analytical work. Several manufacturers of spectrographic equipment had new apparatus on display, and were

invited to describe this during the regular sessions, provided they were willing to receive open discussion and frank criticism from the floor.

Significant improvements in methods of spectrographic analysis were discussed by Dr. W. F. Meggers, of the National Bureau of Standards; by Dr. M. Slavin, of the U. S. Bureau of Mines; by Harry W. Dietert and Carl King, of the Harry W. Dietert Company; and by Drs. Sawyer and Vincent.

Of particular interest to metallurgists were papers on the spectrochemical analysis of tin by B. F. Scribner, of the National Bureau of Standards; of aluminum by H. V. and J. R. Churchill, of the Aluminum Company of America; of tellurium by R. E. Nusbaum and J. W. Hackett, of the Research Laboratories of the General Motors Corporation, and of lead, cadmium and zinc, in dust fumes and ores by H. I. Oshry, J. W. Ballard and H. H. Schrenk, of the U. S. Bureau of Mines.

Particular applications of spectrographic methods were discussed by A. E. Ruehle, of the Bell Telephone Laboratories, who spoke on spectrochemical applications to vacuum tube research; by C. W. Rankin, of the New York State Police, who spoke on applications of the spectrograph to toxicological investigations; and by Daniel Norman and W. W. A. Johnson, of the New England Spectrochemical Laboratories, who discussed the spectrographic analysis of meteorites.

Of special interest to biologists and physicists were the sessions on absorption spectroscopy. Professor W. R. Brode, of Ohio State University, discussed a new automatic recorder of absorption spectra and rotatory dispersion. Another absorption spectrophotometer was described by A. O. Beckman and H. H. Cary, of the National Technical Laboratories. Dr. D. DuBois, of the Yale University School of Medicine, described a new absorption apparatus for the study of rapid chemical reactions. The absorption spectra of various complex organic compounds were discussed by Dr. H. H. Darby, of Columbia University, and Dr. Peter A. Cole, of the U. S. Public Health Service. Dr. Darby and Professor M. G. Mellon, of Purdue University, led discussions on terminologies to be used in new analytical methods involving the spectrograph.

Other papers dealt with film and plate processing equipment and with methods to be used in handling photographic plates for spectrographic analysis. Contributions to this part of the discussion were made by Dr. Jacob Sherman, of the U. S. Navy Yard at Philadelphia, and by Dr. L. W. Strock, of the Simon Baruch Research Institute at Saratoga Springs.

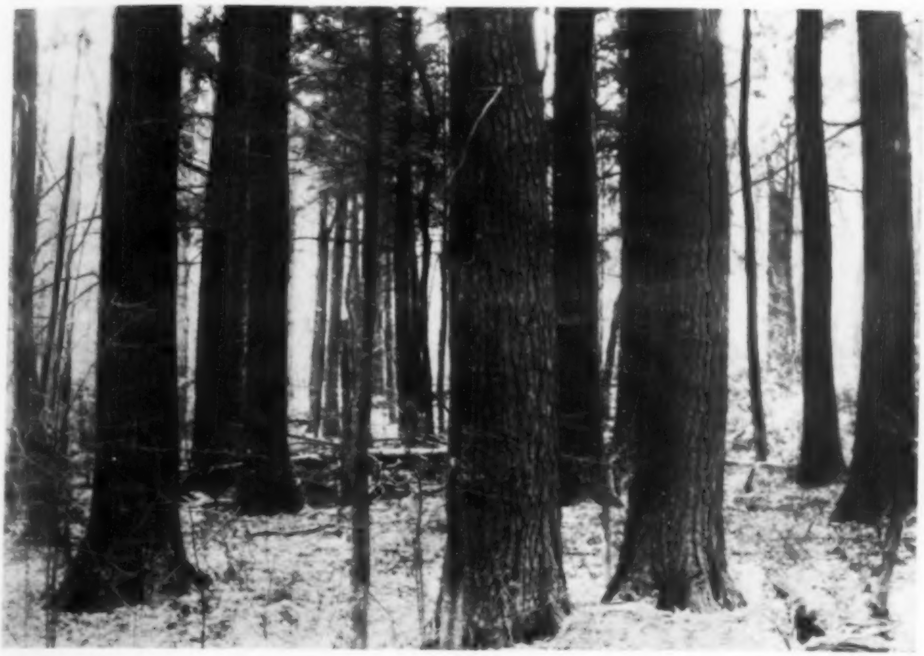
Basic discussions of the physical principles underlying spectrographic analysis were given by Dr. W. F. Meggers, of the National Bureau of Standards, and by Dr. Henry Hemmendinger, of the Massachusetts Institute of Technology.

The conference was enlivened by numerous discussions and interchanges from the floor, a circumstance which probably contributed to the extraordinarily low population of the corridors during the three days of sessions.

G. R. Harrison

A PRIMEVAL LABORATORY IN PENN'S WOODS

The U. S. Forest Service has set aside 4,131 acres of essentially virgin hemlock-beech forest, located on the Allegheny National Forest in northwestern Pennsylvania, to be devoted permanently to scientific use and for the education and enjoyment of the public. This area is located on the northern Allegheny Plateau 7 miles south of the town of Ludlow, and is unique in containing the largest acre-



ANCIENT HEMLOCK INTERSPERSED WITH SMALL BEECH TREES

age of original forest of its type in the East. It is also the largest single remaining body of virgin timber between the Adirondacks of New York State and the Great Smokies of North Carolina. The purchase and reservation of this tract, which was advocated by leading scientists and vigorously promoted by the Pennsylvania Forestry Association, had the support of the late Chief Forester, F. A. Silcox, and was approved by the National Forest Reservation Commission in 1934. Its reservation is an important forward step in the U. S. Forest Service program of permanently preserving natural areas characteristic of native forest and range vegetation in all regions of the United States.

In administering this area the Forest Service recognizes two obligations. First, to preserve the native animal and plant life in their natural state, in so far as this can be done on an area of this size; and second, to stimulate use of the area by competent scientists, naturalists and the lay public to study, enjoy and record the life that goes on in undisturbed northern hardwood forests. To open up this area by motor roads and to provide elaborate facilities for picnicking or camping, thereby encouraging its use as a park, would obviously create disturbances that would profoundly affect both plants and animals. That unavoidable disturbance may be at a minimum; the motor road will terminate at the northern border, where foot trails will lead through choice stands of virgin timber and past points of scenic interest. These trails will be confined to the northern half that is designated as the Tionesta Scenic Area. Here the inspiration and true recreation to be found in a fairly large area of primeval forest may be enjoyed amid towering hemlock 300 to 500 years old and veteran beech 350 years of age. The southern portion, consisting of 2,113 acres and designated as

the Tionesta Natural Area, is dedicated primarily to scientific research and will remain without developed trails.

This tract as a whole has been essentially undisturbed by the activities of man for 500 years, though there has been some oil and gas development within the last 50 years. Contrary to the usual concept, a virgin forest is not static but is responsive to natural forces which tend to tear it down and build it up. During periods of stress, caused primarily by severe droughts, many mature trees die, and greater or smaller openings are created in the forest canopy. Preservation of this area makes possible studying the response of the forest to such catastrophes as drought, windthrow, fire and glaze storms, and observing the way in which natural regeneration takes place after these destructive agents have eliminated the veteran trees.

The species composition of a virgin forest indicates those most likely to persist and succeed under local soil and climate and most suitable for selective cutting for continuous forest production. Likewise the virgin forest in which some species of trees are all-aged and others in even-aged groups suggests the system of forest management which may be used in each case. The number of trees per acre and their quality in original forests also give important keys to the productivity of forest soils and to methods of stand improvement applicable to our second-growth forests. Portions of the virgin forest undergoing cycles of mortality followed by rejuvenation are excellent indicators of ways to secure natural regrowth following man-made harvest cuttings in mature forests.

The Tionesta Natural and Scenic areas possess an interesting animal population of large and small mammals, such as bear, whitetail deer, porcupine, raccoon, bobcat, beaver, muskrat, mink, weasel and snow-shoe hare. Common among

HEMLOCK, BEECH AND YELLOW BIRCH ON LOWER SLOPE OF FORK RUN

A LARGE BEECH TREE
MEASURING 30.6 INCHES IN DIAMETER, IN THE TIONESTA SCENIC AREA.

A SUGAR-MAPLE TREE
MEASURING 29.4 INCHES IN DIAMETER, WITH BEECH AND HEMLOCK IN THE BACKGROUND.

the smaller forms are the red squirrel, chipmunk, two species of deer mice, the short-tailed shrew and the gray squirrel with a preponderance of black forms. Less common are the red-backed mouse, woodland jumping mouse and smoky shrew. The gray fox and the opossum are southern species also found in the Tionesta. There is a great variety of bird life. Reptiles are not common, but certain amphibians are fairly abundant, and at least nine species of fishes are found in the main streams. Among the vertebrate animals the dominant species are generally Canadian Zone types. This forest is especially valuable for studying the inter-relationships among all forms of animal life in a relatively unspoiled or natural environment permitting the unhampered working of biologic laws.

The virgin forest has a great influence on the local climate beneath its canopy and generally ameliorates extremes of temperature, reduces wind movement and lessens evaporation. More information on the so-called microclimate of forests and open areas can be obtained. Likewise the influence of the forest on the protection of watersheds through prevention of erosion, streamflow regulation and soil upbuilding should receive detailed study.

HARDY L. SHIRLEY

FOOTPRINTS 100,000,000 YEARS OLD

FURTHER evidence of the prehistoric monsters that roamed the earth millions of years ago, a group of dinosaur footprints perfectly preserved in limestone, has been uncovered in Bandera County, Texas, by a WPA paleontological project sponsored by the University of Texas.

Considerable scientific interest has been aroused by the find, as these tracks are the first ones that so far have been

discovered in a condition suitable for scientific study. Also interesting is the fact that both the five-toed prints of the huge sauropod or herbivorous dinosaur and the three-toed tracks of the smaller but ferocious carnivorous type were found in the same location.

The tracks were found deeply imbedded in a cretaceous limestone layer underlying some twelve feet of soil along the bank of the West Verde Creek, a few miles southwest of Bandera, Texas. WPA workers, under the supervision of Roland T. Bird of the American Museum of Natural History, carefully cut back the top layers of the soil and gravel and laid bare the prints. The tracks are now being studied and preserved and specimens will be displayed at the American Museum of Natural History in New York City and at the University of Texas Memorial Museum at Austin.

To the trained eye of the scientist the giant five-toed tracks, along the West Verde Creek, tell a story of a whole herd of sauropod dinosaurs which millions of years ago sloughed through the soft, warm mud of an inland sea covering much of Texas. The tracks give evidence of possibly eight or nine of these huge 50-foot-long quadrupeds which belong to the same group as the well-known Brontosaurus. The imprints of one baby belonging to this group were also found.

A perfect row of three-toed, carnivorous dinosaur tracks, cut some three inches deep in the limestone layer, were found. These prints, looking like huge three-toed bird tracks, proceed for fifteen five-foot strides along the exposed portion. Among the carnivore tracks there are also those of a baby, probably no larger than a kangaroo, according to estimates. These prints give every evidence of being those of the erect predatory dinosaurs which roamed in packs and preyed upon the slower herbivorous sauropods.

It is the curiously rounded, five-toed prints of the mammoth sauropod which has caused the most scientific interest, however. Measurements made at the West Verde site indicate that the largest footprint was 32 inches from heel to toe and that this mammoth amphibian walked with a nine-foot stride. From these measurements it is estimated that the largest of this group was approximately 14 feet high at the hips, was about 50 feet long and weighed more than 10 tons.

Although many fossil remains of the giant sauropod, of which Brontosaurus, the "thunder-lizard," is perhaps the best representative, have been discovered in the western and southwestern portion of the United States and Canada, no clear-cut footprints, adaptable to scientific study, have been uncovered before. This is probably due to the fact that the amphibious sauropod spent most of this time in the water, feeding upon marine vegetation; and the mud flats over which he occasionally wandered were subject to wave action and other elements which would destroy the tracks.

A. S.